ANALYSIS OF DATA OBTAINED FROM THE GARFIELD COUNTY AIR TOXICS STUDY – SUMMER 2008

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COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT
AIR POLLUTION CONTROL DIVISION

1.0 INTRODUCTION

Garfield County is located on the western slope of Colorado. It is bounded on the east by the Glenwood Canyon and the Flat Tops Wilderness area and on the west by the Colorado state line. Eastern Garfield County is mountainous, with alpine environments that are home to skiing and numerous other recreational and tourism opportunities. The western third of the County is dominated by desert climates and plateaus, and is sparsely populated by ranchers. The central third of the county is predominantly agricultural. However, this region has recently and rapidly developed into the bedroom communities for the wealthy tourism centers of Eagle and Pitkin counties. In addition, in recent years Garfield County has become home to a rapidly growing energy development industry, with the primary resource of interest being natural gas. This gas field development is expected to expand into the western region of the County in the coming years.

With this information, the Garfield County Public Health Department (GCPHD), in conjunction with the Colorado Department of Public Health and Environment's (CDPHE) Air Pollution Control Division (APCD), and the aid of a Regional Geographic Initiatives Grant administered by the US Environmental Protection Agency's (EPA) Region 8 office, developed and carried out a study of air toxics that took place during the summer of 2008. It should be noted here that the study was intended to be used as a screening tool with the purpose of determining whether or not further, more in depth, air pollution research should be performed in the area. The ultimate goal of the study was to further develop the basis for decisions on how Garfield County can best manage the impacts of air pollution caused by energy development. Through a well-timed combination of targeted ambient air quality monitoring, emission inventory development and community education and outreach, the County and its partners will be able to more fully assess the health, and eventually welfare, effects of emissions from Colorado's most active oil and gas development region on ambient air quality standards and air quality related values.

2.0 METHODS AND EQUIPMENT

The project plan was to design and initiate a short-term targeted air quality monitoring program (using nationally acceptable methods and protocols) that focused on energy development operations based on their proximity to homes and businesses in Garfield County. This monitoring effort was designed to begin characterizing the potential exposure of citizens to a variety of volatile organic compounds (VOC) and fine particulate matter (particulate matter that is < 2.5 microns in diameter). The sampling included residential and business areas that were heavily influenced by local emission sources from energy development operations and large quantities of truck traffic.

The targeted energy development operations chosen were drilling and completion activities, both of which are associated with how natural gas is brought from its underground reservoirs to the earth's surface (extraction process). It should be noted that several processes are required for getting natural gas out of the ground and to its final destination. The scope of this air monitoring effort was not intended to serve as an all encompassing large scale assessment of all possible processes within the energy development industry or address every potential variable (seasonality, temporal, operational, etc.). Rather, it was designed to compare and estimate the potential emissions from these two processes taking place on a well pad.

The quality assurance for sampling design relied mainly on examining as many sources of information about potential sample locations in the study area as possible. To identify sample sites for potential inclusion in the project, monitoring sites were identified from maps provided by the Garfield County GIS Department, existing GCPHD data from previous and current ambient air studies, and by consulting representatives from four of the energy development companies operating within Garfield County.

The project plan was to take all samples for 24-hour periods, following all EPA guidelines for sampling procedures and analysis. Both the 24-hour integrated $PM_{2.5}$ particulate filter samples and 24-hour average NMOC (non-methane organic compound) canister sampling were scheduled based on energy operation schedules that were consistent with the highest levels of activity for a given energy development operation/location. Schedules were also determined based on equipment availability and laboratory turnaround times. Each location consisted of NMOC and $PM_{2.5}$ sampling equipment positioned in four cardinal directions around a specific energy development operation. In addition, a meteorological station and real-time photo ionization detector (PID), for detection of total VOC concentrations, were co-located with the NMOC and $PM_{2.5}$ samplers at one of the cardinal monitoring stations at each location. Duplicate samples and field blanks were also collected at one station at each energy development location for quality assurance purposes.

Due to the complex physical geography in Garfield County, the diurnal wind direction is highly variable from one location to another. Several monitoring background sites were integrated into the project for the measurements made at the energy development operation to be compared against. The sites were intended to be representative of the background contribution of the measured pollutants and included the same equipment as the energy development monitoring sites (excluding the PID). EPA Region 8 and CDPHE provided the samplers, training, and any technical assistance needed throughout the monitoring program.

2.1 METHOD FOR MEASURING PARTICULATE MATTER ($PM_{2.5}$)

Oil and gas development operations such as well drilling and completion activities produce emissions from diesel engines (trucks and drilling rigs) that are within the $PM_{2.5}$ size fraction. $PM_{2.5}$ concentrations were monitored near well drilling and completion activities using standard EPA monitoring protocols such as, EPA Quality Assurance Guidance Document 2.12.

$PM_{2.5}$ was measured using a MiniVol Portable Air Sampler (Airmetrics) and gravimetric analysis. While not a reference method sampler, the Mini-Vol gives results that closely approximate reference method air quality data. The sampler consisted of a 12-volt battery (that can sample for 24 hours without recharging), a small pump, and a timer assembly housed in a body of plastic tubing. A 47mm filter holder assembly was mounted on top of the body. The sampler filter head was adjusted to collect $PM_{2.5}$ only. This was done by changing the impactor in the filter head assembly. The sampler used a 46.2 mm PTFE filter (Whatman) with a 2 micrometer pore diameter, which is the standard filter used for $PM_{2.5}$ sampling. Gravimetric analyses were performed by Inter-Mountain Labs, Sheridan, WY.

The sampler pump drew ambient air through the filter at a constant flow rate. The operator sets the sample flow rate by turning a small potentiometer screw on the main electronic board inside the sampler body. The flow rate was measured using a volumetric primary flow standard (Bios International, Defender 510 Series) traceable to the National Institute of Standards and Technology. The sample “on” and “off” time was determined by setting a battery-powered timer (for 24 hours).

The filter was laboratory-weighed before and after sampling. The weight difference (expressed in micrograms) was divided by the total volume of air collected over the sampling period (expressed in cubic meters) and presented as a total concentration of $PM_{2.5}$ (in micrograms per cubic meter).

2.2 METHOD FOR MEASURING NON-METHANE ORGANIC COMPOUNDS (NMOCS)

NMOC collection and analysis was performed following EPA Organic Compendium Method TO-12, using Summa-polished stainless steel canisters, a stainless steel flow control orifice (Veriflo SC423XL), and gas chromatography/direct flame ionization detection (GC/FID) analysis. EPA Method TO-12 for non-methane organic compounds (NMOCs) was chosen to help characterize ozone precursors; an air quality management topic of increasing interest for the region.

Equipment was provided by Eastern Research Group (ERG), an EPA approved analytical laboratory firm contracted by Garfield County to provide support and laboratory analyses. ERG successfully completed the proficiency audit comparison test (PT) prior to the study. The canisters were evacuated in the lab prior to sampling, so no power was required for operation. GCPHD was responsible for handling the NMOC samples once collected and prepared them for shipment to ERG for laboratory analysis. The sampled canisters were analyzed by ERG for 78 individual NMOCs.

2.3 METHOD FOR MEASURING REAL-TIME VOLATILE ORGANIC COMPOUNDS (VOCS)

Total VOC was measured in real-time using a Rae Systems PPB Rae 3000 photo ionization detector (PID) to supplement the canister sampling. The PID provided part-per-billion sensitivity of VOCs. The response from a PID is nonspecific (i.e. the instrument cannot tell what gas it is responding to).

The handheld unit aspirates a sample at 400 mL/min into the sensing volume, where the stream is illuminated by a high voltage (10.6 eV) ultraviolet lamp. A fraction of the organic molecules absorb the high energy light and eject a negatively charged electron, thereby forming a positively charged molecular ion. The charged particles produce a current that is measured by the sensor electrodes.

A small charcoal absorber was attached to the inlet to remove most of the VOCs and provide a zero/baseline reference. The instrument was calibrated prior to each use using isobutylene gas. A small filter was used on the inlet probe to remove particulates from the air stream. The instrument contains a data-logging capability, which facilitates the collection and downloading of measurement data. The unit can store eight two-point calibration curves.

2.4 METHOD FOR MEASURING METEOROLOGY

Due to funding and location constraints, the meteorological monitoring for this project does not meet EPA recommendations for regulatory requirements. However, they do provide useful information for the monitoring locations and the Garfield County area in general.

The basic configuration of metrological equipment at each location consisted of a RainWise® MK III sensor array and a RainWise® CC-2000 computer interface. The station was co-located with $PM_{2.5}$ and NMOC samplers at each of the sampling sites. The parameters recorded were wind speed, wind direction, temperature, barometric pressure, relative humidity, and precipitation. The sensors were located on top of a tripod tower, approximately 3-meters above the ground, with the exception of the precipitation sensor which was located at ground level. To ensure high quality meteorological data, several steps were taken during installation and initial calibration. These steps included installation of sensor arrays above and away from any structures which could have potentially interfered with wind measurements (i.e. $PM_{2.5}$ units) and the use of a hand held barometer (for ensuring accurate readings from the sensors) during equipment setup. Meteorological data were downloaded following a sampling period via Palm® software.

3.0 MONITORING SITES

There were eight sites chosen to participate in this study. Wells were being completed at four of the eight chosen sites, and were being drilled at the remaining four sites. Both the drilling and completion processes take approximately one week to complete. When monitoring the completion activities, it was decided that sampling would occur during the period prior to achieving salable natural gas—when the flowback from the well is being routed to open top tanks that are venting directly into the air.

Well completion takes place at the end of the drilling process. It is the last step of drilling a gas well, and involves cleaning the well bore and reservoir immediately surrounding the well. Sand, cuttings, and reservoir fluids (including condensate) from the well are collected in an open pit or tank for disposal (in this study, collection was to an open topped tank), and produced natural gas is vented to atmosphere.[1] This is done for the reason that when a new well is initially tapped into, the pressure of the escaping gases is very high and difficult to control. These activities also occur after well workovers (also known as fracing operations), which are conducted to stimulate or

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[1] Regional Air Quality Council (RAQC), *Draft Oil and Gas Ozone Reduction Strategy, Well Completions Section.* Presented at February 26, 2008 RAQC meeting. Available at: http://www.ozoneaware.org/postfiles/documentsandpresentations/oil_gas/A-PCDOZISSUEPAPEROGwellcompletions_000.pdf

prolong production.[1] Well completions are usually a week in duration, with shorter durations in eastern Colorado and longer durations in western Colorado. [2]

Once the pressures have dropped, and the gas becomes salable, it is then re-routed from the open topped tanks to the flowback skid, where it is cleaned up, and routed to the sales line. Garfield County and its partners believe that it is this venting of the non-salable gas that has the highest potential for creating odors, and elevating the concentrations of volatile organic compounds (VOCs) and non-methane organic compounds (NMOCs).

At each monitoring site, several sampling locations were established. Sampling equipment, as described in Section 2, was placed on the north, south, east and west edges of the well pad perimeters.

Figure 1 shows the locations of the eight different sampling sites, with Table 1 listing their coordinates. Sites A, C, E and G were sampled during completion processes, and sites B, D, F and H were sampled during drilling activities. The sites were concentrated between Silt and Parachute, along the Interstate 70 corridor. The maps shown in Figure 1 and Figure 2 below represent a roughly 440 square mile area of Garfield County. The total area of the County is 2,956 square miles. Aside from the oil/natural gas industry, the main economy of the area is largely agricultural.

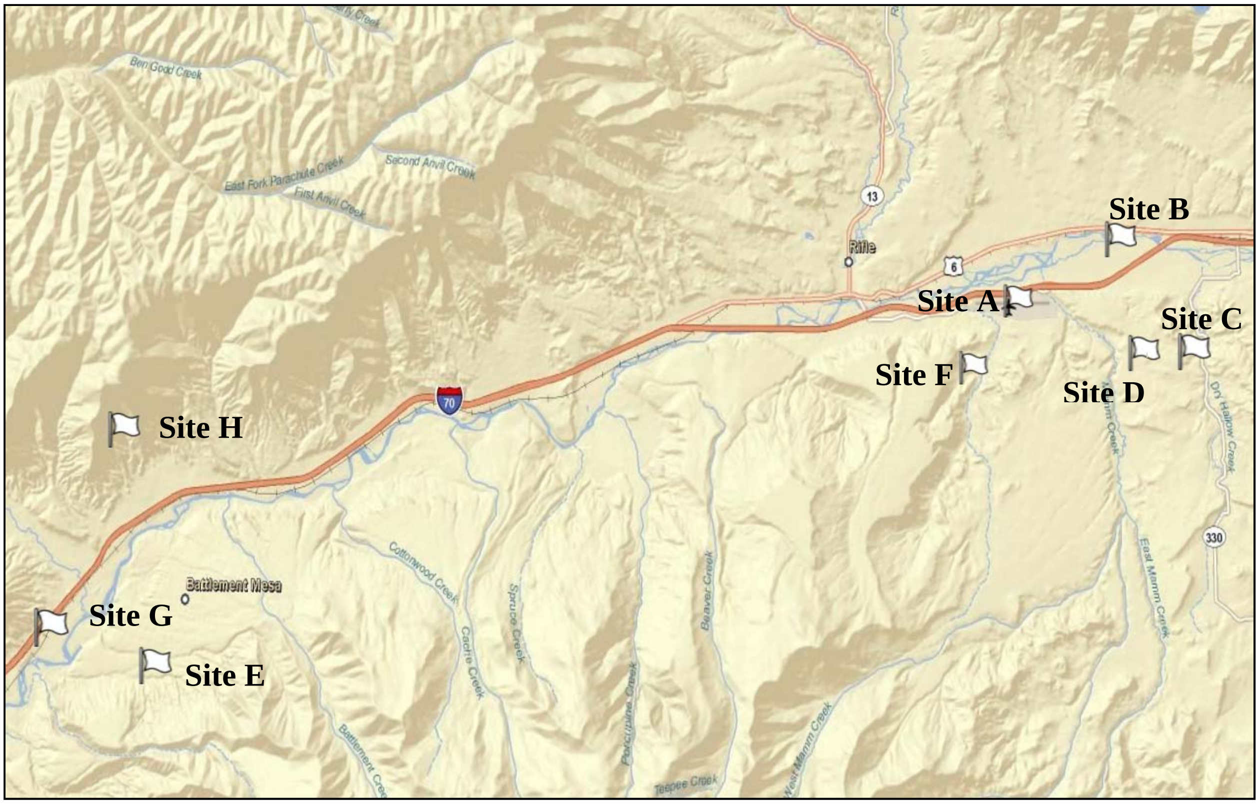

Figure 1. Locations of Sampling Sites in Garfield County

Table 1. Well Site Coordinates

Site	Latitude	Longitude	Sample Dates
A	39.523042°	-107.728636°	06/02-03/2008
B	39.539943°	-107.692331°	07/28-29/2008
C	39.508322°	-107.667964°	07/08-09/2008
D	39.508099°	-107.685190°	07/30-31/2008
E	39.421180°	-108.032453°	07/22-23/2008

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[2] RAQC, *White Paper: Short-Term Ozone Reduction Strategies,* December 4, 2007

Site	Latitude	Longitude	Sample Dates
F	39.504411°	-107.744902°	06/16-17/2008
G	39.431151°	-108.070689°	06/18-19/2008
H	39.486821°	-108.042625°	08/13-14/2008

There is an extensive amount of drilling going on in the Silt to Parachute area, as is indicated by the large number of oil rig symbols shown in Figure 2. Each symbol represents a "bottom hole" location of an individual well, meaning that the symbols are indicative of the number of wells that have been drilled, and not the number of well pad drilling sites. Due to advances in technology, such as horizontal drilling, multiple wells are now drilled from one common pad to reduce surface impacts. An individual well pad can consist of 4 to 24 wells. Many of the wells shown here have been drilled and completed and are producing natural gas or oil products. However, also shown are wells that were drilled and abandoned, and permitted wells that have not been drilled yet. All of this information was included in the data obtained from the Colorado Oil and Gas Conservation Commission (COGCC) website[3], and was unable to be removed from the overall dataset.

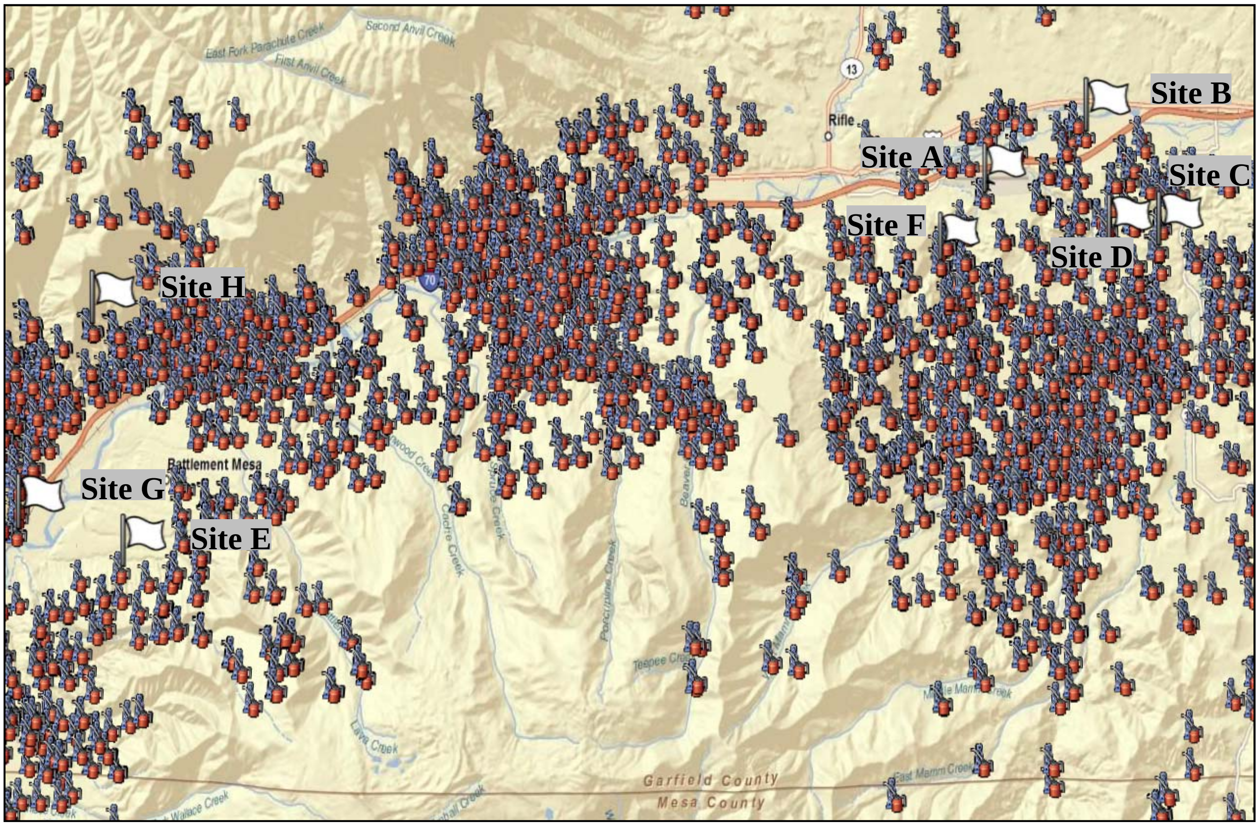

Figure 2. Locations of Individual Wells and Sampling Sites

As of November 6, 2008, there were 5,203 active wells in the County, according to the COGCC. Of those active wells, approximately 4,316 are within the boundaries of the 440 square mile area shown in the maps. This small area is only 15% of the total area of Garfield County, but houses roughly 83% of the actively producing wells. In addition, the area also includes a significant portion of the County's population, as is evidenced in Figure 3. This figure shows the population density of the County using population "blocks" representing 1, 10, 50, 100 and 1000 people each. The importance of determining an accurate inventory of pollutants in this area is easily understood when considering these figures and the above-mentioned information.

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[3] http://cogcc.state.co.us/

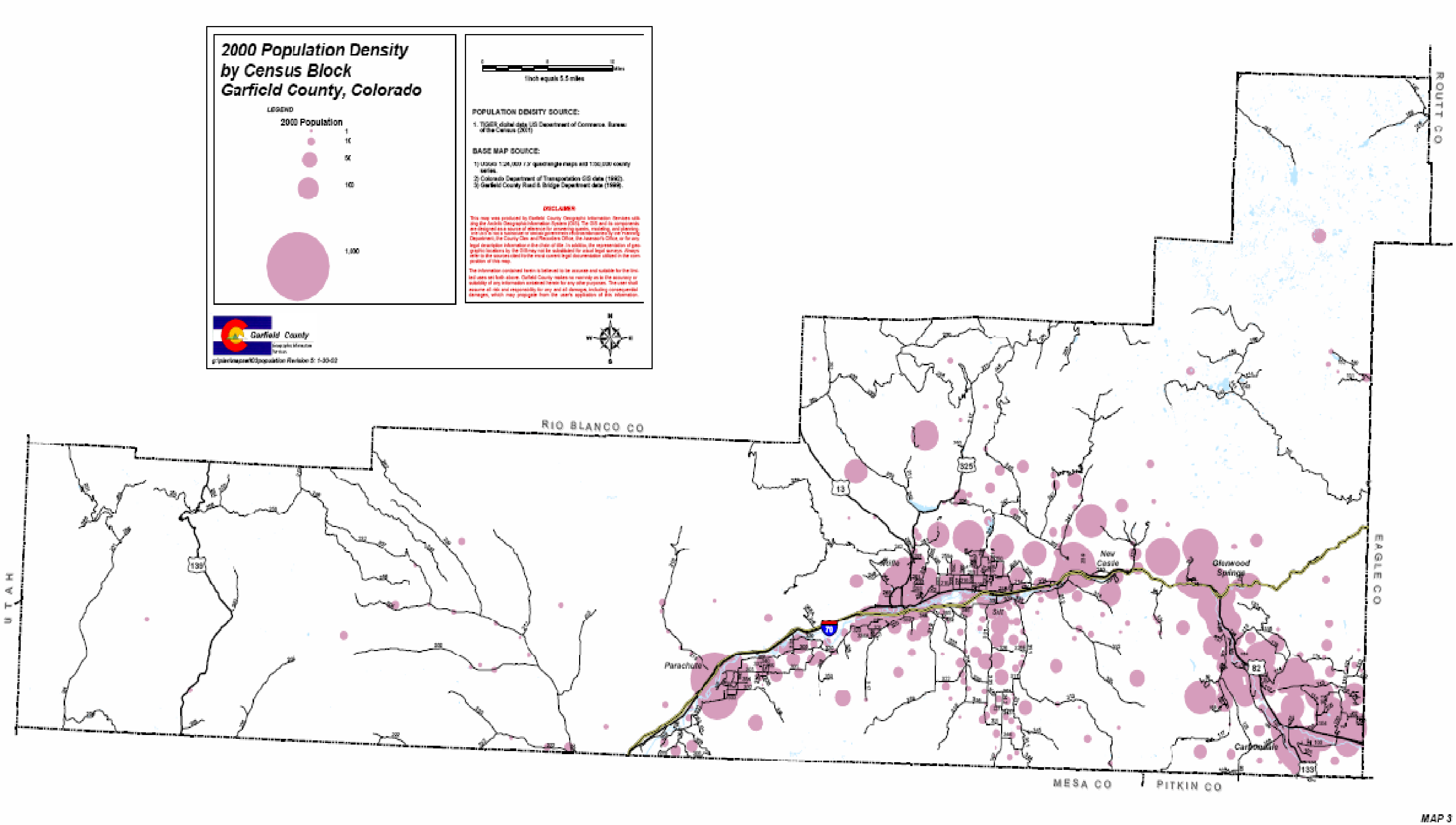

Figure 3. **Population Density of Garfield County via 2000 Census Data**[4]

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[4] http://www.garfield-county.com/docs/6557291200403population.pdf

4.0 DATA ANALYSIS

The following sections describe the processes by which each data set was analyzed, and list the units associated with each different data type. It is crucial that the reader understands the data units and the conversions to and from them so that comparisons between this collected data and that collected in other studies can be made. According to the *EPA's Air Toxics Data Analysis Workbook*, "Section 4: Preparing Data for Analysis," air toxics data can be reported in a range of units.[5] For comparative analyses, however, it is essential to have unit consistency.

4.1 NMOC DATA

Each NMOC air sample collected throughout the study was analyzed for 78 different compounds. These compounds are listed in Table 2, along with their Chemical Abstract Service (CAS) number and Air Quality System (AQS) parameter codes. Also listed in the table are the chemical formulas, the number of carbons on each molecule, and the method detection limits for each compound when being analyzed by this particular method, EPA Compendium Method TO-12. It is essential to know the number of carbons on each molecule, so that a conversion between parts per billion carbon (ppbC) and parts per billion by volume (ppbv) can be made. This conversion is made in order to facilitate comparisons with the VOC results obtained in this study, and those obtained from previous studies. The conversion is made as follows:

$$Concentration\ (ppbv) = \frac{Concentration\ (ppbC)}{Number\ of\ \ Carbons} \tag{1}$$

Table 2. NMOC Analysis Compounds with Associated Method Detection Limits

Compound	CAS #	AQS #	Formula	# of carbons	Method Detection Limit (ppbC)	Method Detection Limit (ppbv)
1,2,3-Trimethylbenzene	526-73-8	45225	C9 H12	9	0.220	0.024
1,2,4-Trimethylbenzene	95-63-6	45208	C9 H12	9	0.240	0.027
1,3,5-Trimethylbenzene	108-67-8	45207	C9 H12	9	0.200	0.022
1,3-Butadiene	106-99-0	43218	C4 H6	4	0.190	0.048
1-Decene	872-05-9	43298	C10 H20	10	0.200	0.020
1-Dodecene	112-41-4	43330	C12 H24	12	0.420	0.035
1-Heptene	592-76-7	43328	C7 H14	7	0.390	0.056
1-Hexene	592-41-6	43245	C6 H12	6	0.430	0.072
1-Nonene	124-11-8	43279	C9 H18	9	0.320	0.036
1-Octene	111-66-0	43145	C8 H16	8	0.310	0.039
1-Pentene	109-67-1	43224	C5 H10	5	0.120	0.024
1-Tridecene	2437-56-1	43142	C13 H26	13	0.420	0.032
1-Undecene	821-95-4	43299	C11 H22	11	0.170	0.015
2,2,3-Trimethylpentane	564-02-3	43292	C8 H18	8	0.310	0.039
2,2,4-Trimethylpentane	540-84-1	43250	C8 H18	8	0.220	0.028
2,2-Dimethylbutane	75-83-2	43244	C6 H14	6	0.140	0.023
2,3,4-Trimethylpentane	565-75-3	43252	C8 H18	8	0.180	0.023
2,3-Dimethylbutane	79-29-8	43284	C6 H14	6	0.200	0.033
2,3-Dimethylpentane	565-59-3	43291	C7 H16	7	0.390	0.056
2,4-Dimethylpentane	108-08-7	43247	C7 H16	7	0.240	0.034
2-Ethyl-1-butene	760-21-4	43236	C6 H12	6	0.430	0.072
2-Methyl-1-butene	563-46-2	43225	C5 H10	5	0.200	0.040
2-Methyl-1-pentene	763-29-1	43246	C6 H12	6	0.430	0.072
2-Methyl-2-butene	513-35-9	43228	C5 H10	5	0.200	0.040

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[5] http://www.epa.gov/ttn/amtic/files/ambient/airtox/workbook/AirtoxWkbk4Preparingdataforanalysis.pdf

Compound	CAS #	AQS #	Formula	# of carbons	Method Detection Limit (ppbC)	Method Detection Limit (ppbv)
2-Methylheptane	592-27-8	43960	C8 H18	8	0.180	0.023
2-Methylhexane	591-76-4	43263	C7 H16	7	0.180	0.026
2-Methylpentane	107-83-5	43285	C6 H14	6	0.080	0.013
3-Methyl-1-butene	563-45-1	43282	C5 H10	5	0.200	0.040
3-Methylheptane	589-81-1	43253	C8 H18	8	0.200	0.025
3-Methylhexane	589-34-4	43249	C7 H16	7	0.230	0.033
3-Methylpentane	96-14-0	43230	C6 H14	6	0.180	0.030
4-Methyl-1-pentene	691-37-2	43234	C6 H12	6	0.430	0.072
Acetylene	74-86-2	43206	C2 H2	2	0.110	0.055
a-Pinene	80-56-8	43256	a-C10 H16	10	0.320	0.032
Benzene	71-43-2	45201	C6 H6	6	0.240	0.040
b-Pinene	127-91-3	43257	b-C10 H16	10	0.200	0.020
cis-2-Butene	590-18-1	43217	C4 H8	4	0.190	0.048
cis-2-Hexene	7688-21-3	43290	C6 H12	6	0.430	0.072
cis-2-Pentene	627-20-3	43227	C5 H10	5	0.190	0.038
Cyclohexane	110-82-7	43248	C6 H12	6	0.220	0.037
Cyclopentane	287-92-3	43242	C5 H10	5	0.080	0.016
Cyclopentene	142-29-0	43283	C5 H8	5	0.200	0.040
Ethane	74-84-0	43202	C2 H6	2	0.090	0.045
Ethylbenzene	100-41-4	45203	C8 H10	8	0.210	0.026
Ethylene	74-85-1	43203	C2 H4	2	0.070	0.035
Isobutane	75-28-5	43214	C4 H10	4	0.080	0.020
Isobutene/1-Butene	115-11-7 / 106-98-9	43127 (43270/43280)	C4 H8 / C4 H8	4	0.140	0.035
Isopentane	78-78-4	43221	C5 H12	5	0.170	0.034
Isoprene	78-79-5	43243	C5 H8	5	0.200	0.040
Isopropylbenzene	98-82-8	45210	C9 H12	9	0.320	0.036
m-Diethylbenzene	141-93-5	45218	C10 H14	10	0.180	0.018
Methylcyclohexane	108-87-2	43261	C7 H14	7	0.150	0.021
Methylcyclopentane	96-37-7	43262	C6 H12	6	0.130	0.022
m-Ethyltoluene	620-14-4	45212	C9 H12	9	0.150	0.017
m-Xylene/p-Xylene	108-38-3 / 106-42-3	45109 (45205/45206)	C8 H10 / C8 H10	8	0.310	0.039
n-Butane	106-97-8	43212	C4 H10	4	0.110	0.028
n-Decane	124-18-5	43238	C10 H22	10	0.200	0.020
n-Dodecane	112-40-3	43141	C12 H26	12	0.420	0.035
n-Heptane	142-82-5	43232	C7 H16	7	0.200	0.029
n-Hexane	110-54-3	43231	C6 H14	6	0.230	0.038
n-Nonane	111-84-2	43235	C9 H20	9	0.170	0.019
n-Octane	111-65-9	43233	C8 H18	8	0.240	0.030
n-Pentane	109-66-0	43220	C5 H12	5	0.100	0.020
n-Propylbenzene	103-65-1	45209	C9 H12	9	0.190	0.021
n-Tridecane	629-50-5	43143	C13 H28	13	0.420	0.032
n-Undecane	1120-21-4	43954	C11 H24	11	0.170	0.015
o-Ethyltoluene	611-14-3	45211	C9 H12	9	0.290	0.032
o-Xylene	95-47-6	45204	C8 H10	8	0.170	0.021
p-Diethylbenzene	105-05-5	45219	C10 H14	10	0.120	0.012
p-Ethyltoluene	622-96-8	45213	C9 H12	9	0.260	0.029
Propane	74-98-6	43204	C3 H8	3	0.180	0.060
Propylene	115-07-1	43205	C3 H6	3	0.070	0.023

Compound	CAS #	AQS #	Formula	# of carbons	Method Detection Limit (ppbC)	Method Detection Limit (ppbv)
Propyne	74-99-7	43144	C3 H4	3	0.180	0.060
Styrene	100-42-5	45220	C8 H8	8	0.250	0.031
Toluene	108-88-3	45202	C7 H8	7	0.330	0.047
trans-2-Butene	624-64-6	43216	C4 H8	4	0.130	0.033
trans-2-Hexene	4050-45-7	43289	C6 H12	6	0.430	0.072
trans-2-Pentene	646-04-8	43226	C5 H10	5	0.190	0.038

In addition to the listed compounds, the sum of the speciated non-methane organic compounds (SNMOC), the sum of the unknown organic compounds and the total non-methane organic compounds (TNMOC) are also reported. The SNMOC and TNMOC concentrations are detected via the methods listed in Section 2.0, and give a value for the total amount of non-methane organic compounds detected in that particular sample. The SNMOC concentrations are broken down into detectable concentrations for each of the 78 species of interest (listed above), and their results are then summed to obtain the value for the total SNMOC.

To obtain the sum of the unknown species, the SNMOC value is subtracted from the TNMOC value. When the overall totals of the NMOC concentrations are discussed, the SNMOC, TNMOC and unknown concentrations are presented in ppbC instead of ppbv throughout this report, as a conversion to ppbv is not possible since the exact number of carbons is not known for the TNMOC concentration. Again, individual species concentration data will be presented as ppbv throughout this report, instead of ppbC. This is done in an effort to maintain unit consistency, and to facilitate data comparison.

4.2 VOC REAL-TIME DATA

The VOC real-time data obtained were reported as one-minute averages of three parameters: the minimum, average and maximum values obtained during the continuous air sampling. The values are reported in ppbv, so no conversions were necessary. In all future mentions of these data, the average values were used for comparison purposes, instead of the recorded minimums or maximums, except where otherwise noted. These averages were plotted with the wind speed and humidity data obtained from the meteorological equipment to determine any correlations between the data sets, and were used to develop hourly and 24-hour averages.

4.3 METEOROLOGICAL DATA

The meteorological (met) data obtained also required no conversions. The monitor recorded one-minute averages of the temperature (˚F), humidity (%), atmospheric pressure (in. Hg), wind direction (0-360 degrees), wind speed (mph) and wind chill temperature (˚F). From these values, the wind direction frequency was calculated by counting the number of times the instrument recorded a positive value for the wind speed and its associated direction. This allowed a determination of the primary wind direction at the sites. In addition to the wind direction frequency, also calculated were the frequencies with which VOC concentrations were detected with a measured wind speed and with no measured wind speed. Finally, the frequency of times there was no measurable wind speed or concentration detected was also computed.

4.4 PM$_{2.5}$ DATA

The PM$_{2.5}$ concentration data was reported by the lab in micrograms per meter cubed (μg/m^3). The concentration values were obtained by dividing the net weight of the particulates that accumulated on the filter over a 24 hour period, by the total volume of air drawn through the filter over that same 24 hour period. An example calculation is shown below.

$$\frac{\left[Mass_{used\ filter}\left(in\ mg\right)-Mass_{unused\ filter}\left(in\ mg\right)\right]\times\left[\frac{1000\ \mu g}{1\ mg}\right]}{Sample\ Volume\ \left(in\ m^{3}\right)}=PM_{2.5}\ Concentration\left(in\ \frac{\mu g}{m^{3}}\right)\quad(2)$$

$$\frac{\left[141.335\ mg\ -141.275\ mg\right]\times\left[1000\ \mu g/1\ mg\right]}{7.4904\ m^{3}}=8.01\ \mu g/m^{3}\quad(3)$$

5.0 RESULTS

The data obtained during the course of this study will be broken down and analyzed as follows. An initial section will be devoted to discussing the data from the drilling sites. A section discussing the completion sites data will follow it. The final section will contain a comparison of the drilling versus completion data. Tables of the various NMOC compound concentrations are presented in the appendices at the end of this report. The concentrations listed were corrected for any non-detectable/non-reportable compounds via the currently accepted practice of replacing their concentration data with half the value of the method detection limit of the compound. This provides a more conservative view of potential air pollution impacts. The graphs also present in the appendices reflect this convention. All data presented in this section of the report do not follow this convention, however. The compounds that were not detectable or reportable are listed out in the drilling and completion summary sections, but are not discussed in the results for each individual site.

In addition to the inter-comparisons made, the NMOC data set is also compared to data obtained from a CDPHE study done in 2006 along Colorado's Front Range. The sample collection and analysis procedures, as well as the data analysis/validation procedures for the Front Range study were carried out in the same manner as this study. EPA Compendium Method TO-12 was used, followed by gas chromatography/direct flame ionization detection (GC/FID) analysis.

It is important to note here that the data obtained by this study provides only a "snapshot" of conditions at that particular time and place. They are not representative of the entire region, as there were only eight well pads sampled. Instead, they are indicative of the conditions at these particular sites; conditions that could be experienced at any of the wells being drilled or completed at any given time in Garfield County, given the same type of circumstances seen at these sites. They serve as an indicator of the possible emissions potentials that could be experienced during these processes. Also noteworthy is the fact that only one company at one of the sites provided activity logs and information pertaining to what was taking place during the period that the samplers were running. Without that documentation it is difficult to draw any concrete conclusions as to why certain levels of various compounds were seen at the sites.

5.1 DRILLING DATA

5.1.1 SITE B

The placement of the samplers around drilling Site B is shown in Figure 4. The orange colored balloons indicate the sampling locations, while well locations are marked by the presence of the drill rig symbols. The background site was located approximately one-third of a mile northwest of the well pad site. The other four sampling areas were located in the approximate cardinal directions surrounding the pad. As can be seen from the image in Figure 4, the land was previously an agricultural area, but has since been partially converted to a drilling area. There are also two other well pads with actively producing wells that are in close proximity to the sampling areas. The longitude and latitude coordinates for each of the sampling sites shown, in addition to the type of instruments installed at each site, is included in Table 3. As can be seen from the table, each site housed NMOC and particulate samplers, with the east site containing the duplicate NMOC and $PM_{2.5}$ samplers in addition to the continuous VOC monitor and meteorological samplers.

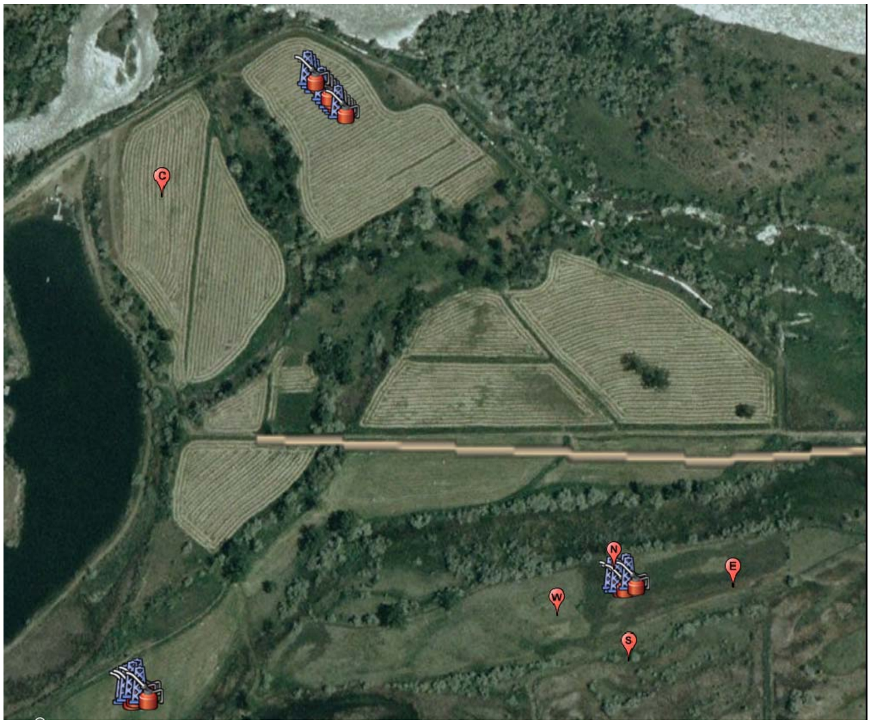


Figure 4. **Site B Sampling Locations and Surrounding Wells**

Table 3. Site B Instrument Locations

Site	Sampling Location	Latitude	Longitude	Instrument Types
B	North (N)	39.540183°	107.692550°	NMOC, $PM_{2.5}$
	South (S)	39.539467°	107.692400°	NMOC, $PM_{2.5}$
	East (E)	39.540050°	107.691333°	NMOC(x2), VOC, MET, $PM_{2.5}$(x2)
	West (W)	39.539817°	107.693133°	NMOC, $PM_{2.5}$
	Control (C)	39.543133°	107.697183°	NMOC, $PM_{2.5}$

The data obtained from the particulate samplers is shown in Figure 5. All samples were taken for a 24-hour period, and the averages calculated over that same time period. The data show that there was a discrepancy between the duplicate samplers located at the eastern monitoring station. The primary sampler recorded a concentration that was 10.4 $\mu g/m^3$, while the secondary sampler recorded a value of 6.8 $\mu g/m^3$. The average of the two is 8.6 $\mu g/m^3$, and the relative percent difference (RPD) between the two values is 42%. The relative percent difference was calculated using the following equation:

$$RPD = \left(\frac{\left| 10.4\frac{\mu g}{m^3} - 6.8\frac{\mu g}{m^3} \right|}{10.4\frac{\mu g}{m^3} + 6.8\frac{\mu g}{m^3}} \right) \times 200 = 42\% \qquad (4)$$

In fact, the secondary sampler's value was the lowest recorded for all the site's monitors, lower than even the background monitor. Aside from this sampler, all other samplers recorded values above 8 $\mu g/m^3$, The average for the well pad came to 9.3 $\mu g/m^3$, with the background site value at 8.2 $\mu g/m^3$, giving an RPD of 13% between the two values. The south, west and primary east sites all recorded values that were very similar, with relative percent differences of 0.97% (between East 1 and West), 1.9% (between East 1 and South), and 0.98% (between West and South). All the values obtained were well below the value of the 24-hour maximum exposure EPA standard for $PM_{2.5}$ of 35 $\mu g/m^3$.

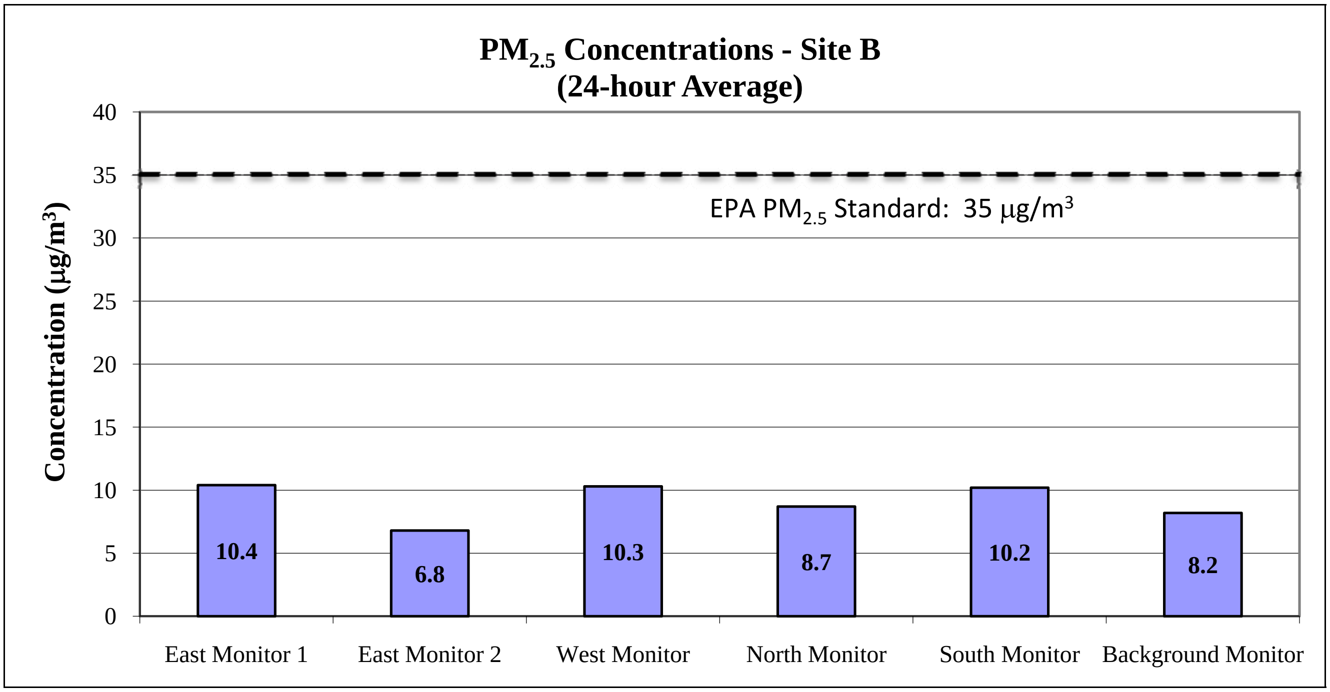


Figure 5. **Site B $PM_{2.5}$ Concentrations**

Figure 5 shows that there were similar particulate concentrations recorded at the West, South and East 1 monitors. With primary winds from the south to southeasterly area approximately 7 % of the time, and from the west just under 15% of the time, theoretically the eastern monitors should have seen the largest particulate concentrations. While this was the case with the East 1 monitor, it was not with the collocated East 2 monitor. There appears to be little effect of wind speed or direction on the particulate data at this location, as the particulate concentrations are rather uniform across the well pad.

An analysis of the meteorological data shows that the primary wind direction observed at Site B was from the west to west-northwest, as is seen in Figure 6. The wind data were averaged over a 24-hour time period. Nearly 30% of the time the wind blew from one of those two directions, with frequencies of less than 10% in all other directions. Also listed in Figure 6 are the frequencies with which there was a VOC concentration detected at the same time there was a measurable wind speed recorded. Nearly 25% of the time when there was a measurable wind speed from the west, VOC concentrations were also detected. This value falls off to just fewer than 20% for the WNW direction, and is close to 10% for the WSW, S and SSE directions.

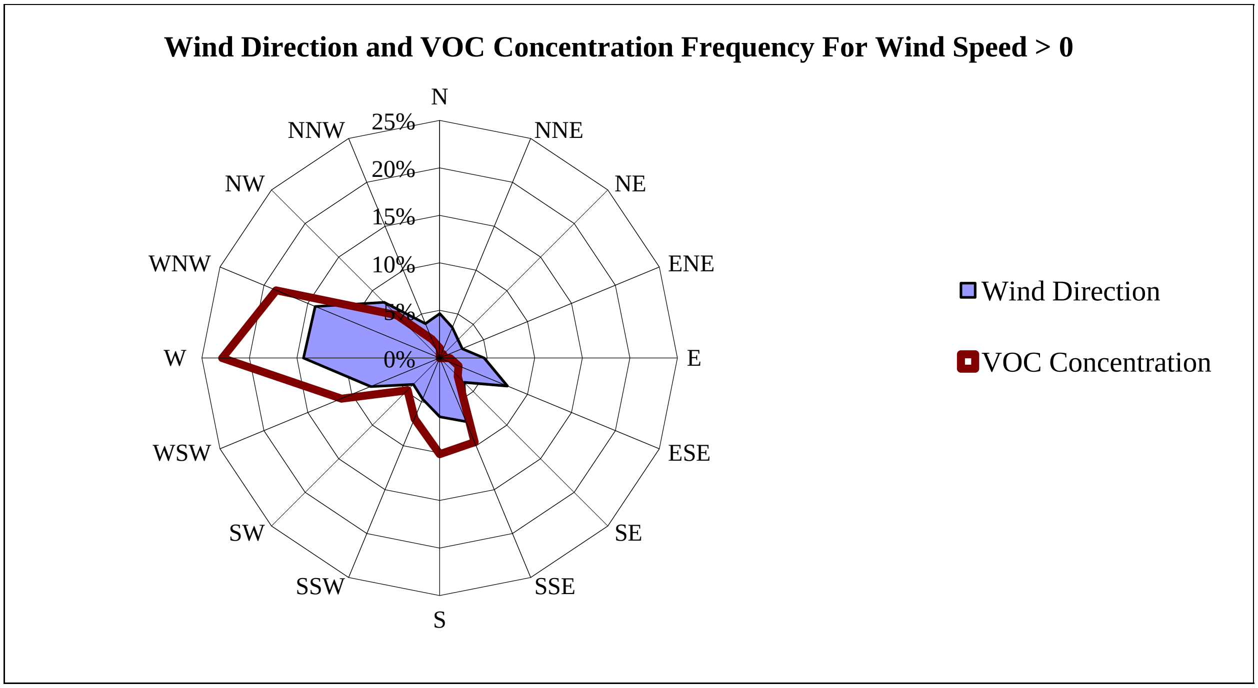


Figure 6. Wind Direction and VOC Concentration Frequencies for Site B

The breakdown of wind speed and concentration is better illustrated in Figure 7. Here, the figure shows that 37% of the time there was no measurable wind speed or VOC concentration detected, as they were below the detection level (BDL). Twelve percent of the time there was both a wind speed and a concentration recorded. Twenty-two percent of the time, however, there was no measured wind speed recorded but there was a VOC concentration recorded. The remaining 30% is due to measured wind speeds and no measured concentrations. During the sampling session, nearly 67% of the time there was no VOC concentration detected; meaning that for over one-third of the sampling time (a 27-hour period where both the VOC and met instrument were running), or approximately a total of 9 hours, VOC concentrations were detected.

Another illustration of the wind speed and concentration data is shown in Figure 8. The time series graph of the real-time VOC concentrations and wind speeds shows “bursts” of activity from approximately 15:00 to 17:30, 19:15 to 21:30 on 7/28/2008, and 00:00 to 03:15, 04:15 to 08:00 and 10:00 to 15:30 (interspersed with short lulls) on 7/29/2008. The last period shows winds with an average speed of 12 mph, primarily from the SSW to SSE direction, and concentration increases to 518 ppbv. The first period shows VOC concentration spikes to 1,950 ppbv and 1,823 ppbv. At the same time the spikes were occurring, the meteorological station recorded winds from the W to WSW direction, with an average speed of 12 mph. These concentration spikes are the largest seen during the sampling period. Considering that the meteorological station and VOC analyzer were located at the eastern side of the well pad, and that a westerly wind would blow directly across the production facilities, drilling rig, etc., the elevated concentrations make sense. The 04:15 to 08:00 period has prolonged periods of concentrations averaging 43 ppbv, with a few spikes to higher levels over 600 ppbv. During this time there was little to no wind detected by the met station. This time period is a large contribution to the 22% of the time that there were no wind speeds and a VOC concentration detected. The highest VOC concentration spikes were seen when there were westerly winds (blowing across the well pad facilities). The average VOC concentration observed over the 27-hour sampling period was 25 ppbv. The 1-minute maximum and 27-hour average VOC concentration values observed by the monitor are listed in Table 4.

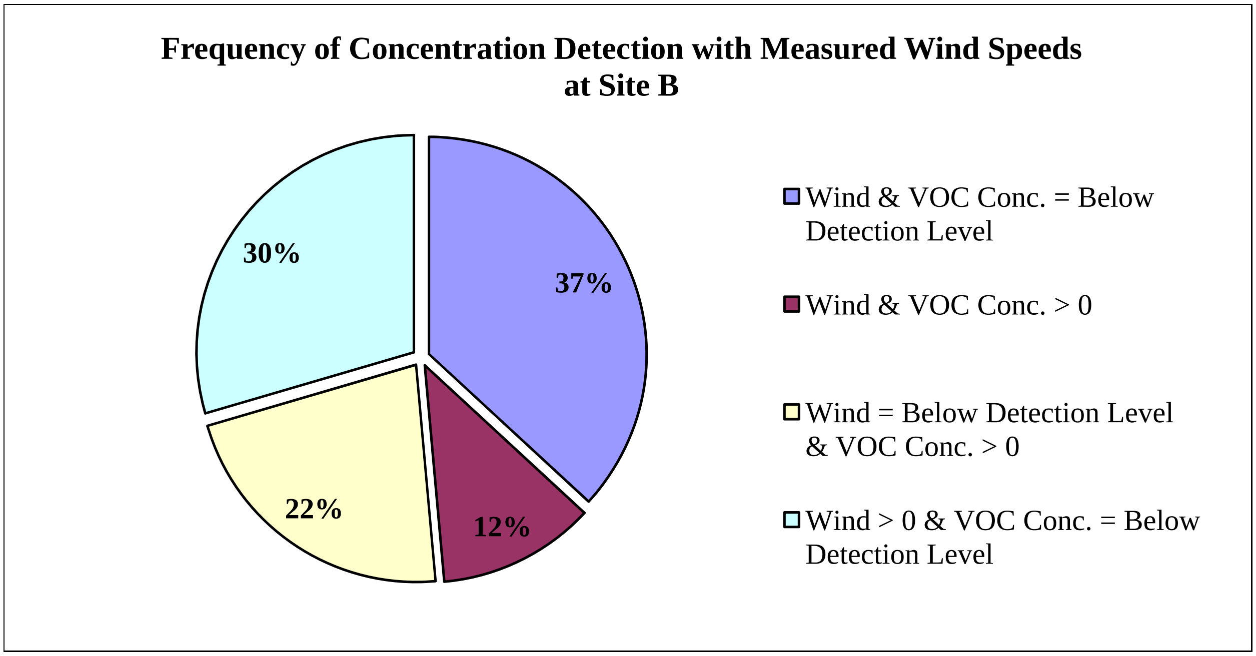


Figure 7. **Frequencies of Wind Speed and VOC Concentration Detection at Site B**

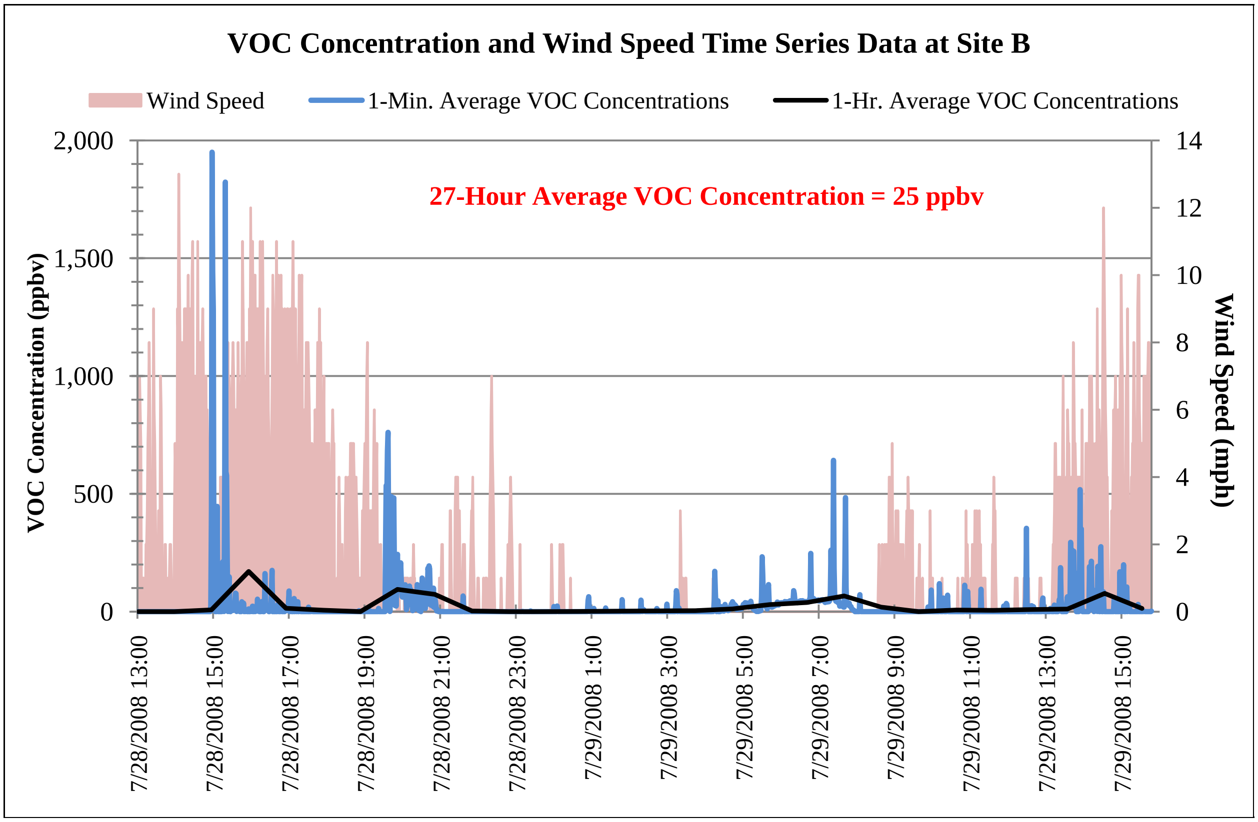


Figure 8. **Time Series Data for VOC Concentrations and Wind Speeds at Site B**

Table 4. Maximum and Average VOC Concentrations

Maximum VOC Concentration (taken from 1 minute avgs.)	**Average VOC Concentration (averaged over 27 hours)**
1,950 ppbv	25 ppbv

Figure 9 shows the NMOC concentrations obtained over a 27-hour sampling period at Site B. The average NMOC concentrations for the pad were 247 ppbC for SNMOC, 118 ppbC for unknowns, and 365 ppbC for TNMOC. Those same values for the background site were 251, 73 and 324 ppbC, respectively. Table 5 lists the average of all the NMOC concentrations obtained from each monitor around the well pad, as well as the concentrations observed at the background monitor and the relative percent difference of the two samples. The average concentrations obtained for the entire pad were similar to those recorded at the background site, with only the SNMOC average having a slightly lower value than the background site value.

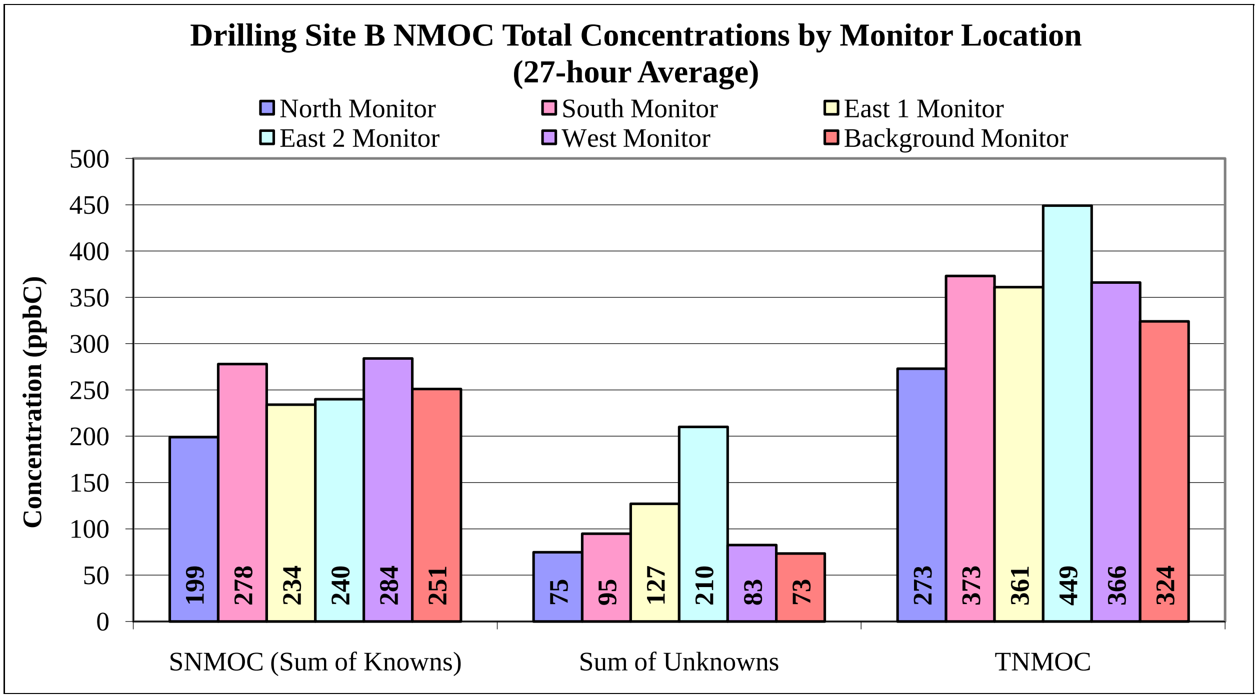


Figure 9. Site B SNMOC, TNMOC and Unknown Concentrations by Sampling Location

Table 5. Well Pad Average and Background Monitor NMOC Concentrations and RPD

	Well Pad Avg. Concentration ppbC (27-hour avg.)	**Background Monitor Concentration ppbC (27-hour avg.)**	**RPD %**
SNMOC	247	251	2
Sum of Unknowns	118	73	47
TNMOC	364	324	12

The eastern sampling site housed not only the VOC, met and $PM_{2.5}$ samplers, but also the duplicate NMOC samplers. The remaining sites contained only NMOC and $PM_{2.5}$ samplers. This is important, as it was previously established that the primary winds at this monitor were from a westerly direction. Figure 9 indicates that the duplicate samplers at the east monitor detected some of the highest concentrations of TNMOCs. Those monitors have the first and fourth highest concentrations with values of 449 and 361 ppbC, respectively. The south monitor ranks second at 373 ppbC, and the west monitor is third at 366 ppbC. Note that the duplicate samplers at the east monitoring site recorded different TNMOC concentrations, as was also seen with the particulate samplers at this location. Table 6 lists the compounds that were detected in each of the NMOC samples taken from the collocated eastern monitors. Many of the compounds have RPD values that are 12% or less, with an average RPD of 13% for the dataset.

Table 6. Duplicate NMOC Sample Concentrations and RPD

ANALYTE	RESULT 1 (ppbC)	RESULT 2 (ppbC)	RPD (%)
1,2,3-Trimethylbenzene	2.77	2.48	11.0
1,2,4-Trimethylbenzene	0.493	0.687	32.9
1-Dodecene	0.349	0.553	45.2
1-Heptene	0.567	0.644	12.7
1-Hexene	0.223	0.271	19.4
1-Pentene	0.254	0.272	6.8
2,2,4-Trimethylpentane	0.151	0.161	6.4
2,2-Dimethylbutane	0.597	0.662	10.3
2,3,4-Trimethylpentane	0.222	0.16	32.5
2,3-Dimethylbutane	1	1.05	4.9
2,3-Dimethylpentane	0.509	0.517	1.6
2,4-Dimethylpentane	0.458	0.407	11.8
2-Methyl-1-butene	1.89	1.68	11.8
2-Methylheptane	0.55	0.591	7.2
2-Methylhexane	1.04	1.13	8.3
2-Methylpentane	4.97	4.69	5.8
3-Methylheptane	0.416	0.461	10.3
3-Methylhexane	1.11	1.16	4.4
3-Methylpentane	2.41	2.39	0.8
4-Methyl-1-pentene	0.813	0.422	63.3
Acetylene	0.631	0.604	4.4
a-Pinene	0.367	0.426	14.9
Benzene	1.32	1.35	2.2
cis-2-Butene	0.166	0.167	0.6
cis-2-Pentene	0.159	0.111	35.6
Cyclohexane	2.58	2.65	2.7
Cyclopentane	0.667	0.677	1.5
Cyclopentene	0.753	0.844	11.4
Ethane	54.6	55.4	1.5
Ethylbenzene	0.356	0.426	17.9
Ethylene	1.41	1.26	11.2
Isobutane	16.3	16.7	2.4
Isobutene/1-Butene	7.5	5.9	23.9
Isopentane	22.6	25.1	10.5
Isoprene	3.3	2.92	12.2
Methylcyclohexane	4.67	4.9	4.8
Methylcyclopentane	2.17	2.18	0.5
m-Ethyltoluene	1.45	1.55	6.7
m-Xylene/p-Xylene	1.64	1.75	6.5
n-Butane	18.6	18.7	0.5
n-Decane	1.36	1.43	5.0
n-Dodecane	1.4	1.6	13.3
n-Heptane	2	2.24	11.3
n-Hexane	4.56	4.95	8.2
n-Nonane	0.717	0.891	21.6
n-Octane	1.67	1.51	10.1

ANALYTE	RESULT 1 (ppbC)	RESULT 2 (ppbC)	RPD (%)
n-Pentane	9.38	9.59	2.2
n-Tridecane	0.388	0.76	64.8
n-Undecane	2.14	2.06	3.8
o-Xylene	0.547	0.608	10.6
p-Ethyltoluene	0.193	0.3	43.4
Propane	42	42.7	1.7
Propylene	0.813	0.907	10.9
SNMOC (Sum of Knowns)	233	239	2.5
Sum of Unknowns	131	166	23.6
TNMOC	364	405	10.7
Toluene	2.7	3.23	17.9
trans-2-Butene	0.244	0.21	15.0
trans-2-Pentene	0.257	0.223	14.2

The SNMOC concentrations for each of the monitoring sites around the pad are similar, and are all within 85 ppbC of each other. There is a large difference between the sums of their unknown concentrations, however. The primary east monitor saw unknown concentrations at 127 ppbC, with the secondary monitor observing approximately 210 ppbC. The remaining monitors recorded unknown concentrations that were under 100 ppbC. The secondary east monitor recorded the highest level of unknown concentrations for the pad, with nearly 47% of the TNMOC concentration being due to unknown species. The eastern monitors showed lower known concentrations than all but the north monitor. In addition, the background monitor showed higher SNMOC and TNMOC concentrations than the north monitor. None of the sampling monitors experienced SNMOC concentrations that were above the upper detection limit (UDL) of the laboratory.

At the north monitor, the highest NMOC concentrations recorded were those of ethane (~23 ppbv) and propane (~10 ppbv). All other compounds detected had concentrations of 5 ppbv or less. A similar occurrence was seen at all of the monitors, including the background. There were 27 non-detected/non-reportable compounds of the 78 tested for. The concentrations of isobutene, isopentane and n-butane all had concentrations that hovered around the 5 ppbv mark as well. Tables and graphs showing the individual species and their concentrations can be found in Appendix B at the end of this report. Those tables and graphs include the corrected values for the non-detected species, but those values are not discussed here. A graph of the ethane and propane concentrations seen at each of the five sampling areas around Site B, seen in Figure 10, indicates that the propane concentration appears to be well distributed, with values ranging between 10 and 17 ppbv. Concentrations of ethane were somewhat more varied however, ranging from 22 to near 40 ppbv.

Like the north site, the east site had ethane and propane as its highest speciated concentrations at 27 and 14 ppbv at both samplers. Also similar was the fact that at the primary east site there were 26 compounds that were not detected nor had concentrations that were under the minimum detectable level (MDL), and at the secondary east site there were 25. At the secondary site 1,3,5-trimethylbenzene and m-diethylbenzene were not detected, but were detected at the primary east site. Also different was the fact that 1-dodecene, n-propylbenzene and o-ethyltoluene were not detected at the primary site, but were detected at the secondary site. Overall, there were 18 compounds that were consistently not detected at all of the sites, and 16 that were non-detects at various sites around the pad.

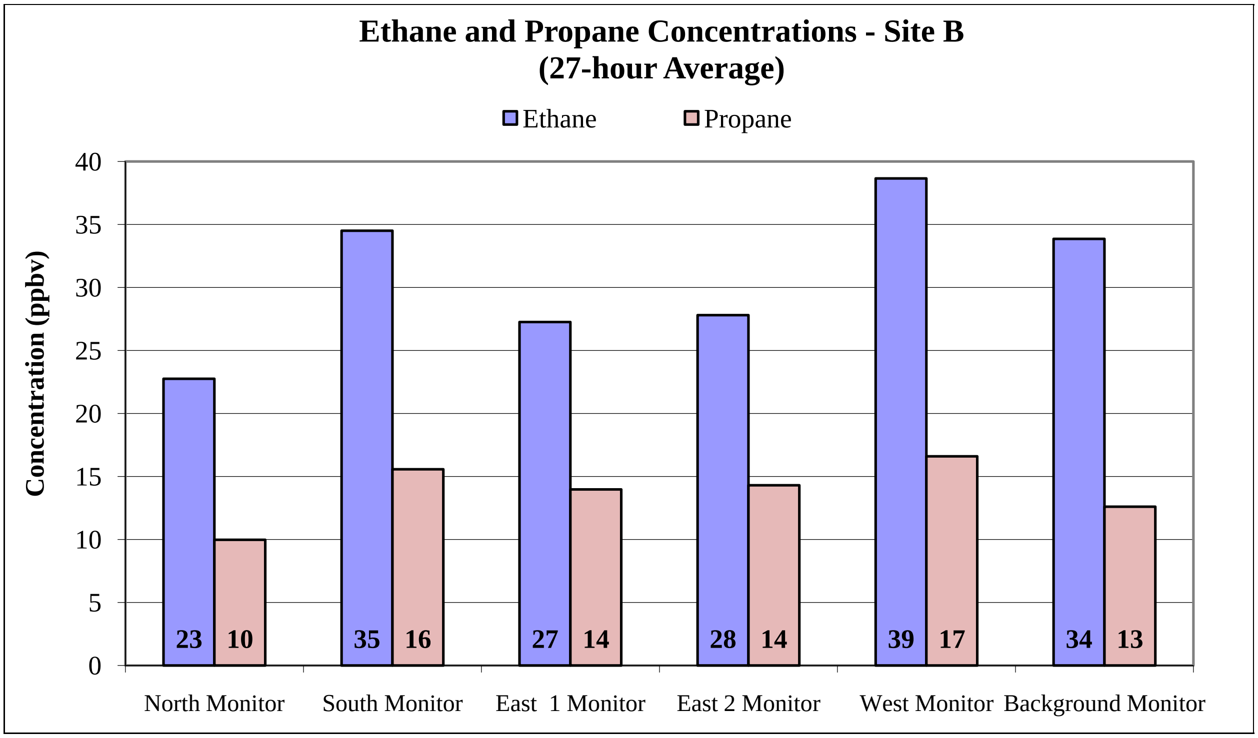


Figure 10. Ethane and Propane Concentrations at Site B

The highest number of non-detects was seen at the west monitor with 29. The background monitor was a close second with 28, and the north monitor was third with 27. As previously mentioned, the background monitor also had larger TNMOC and SNMOC values than the north monitor did, and it was located approximately 1/3 of a mile to the northwest of the well pad. The TNMOC concentrations recorded around the well pad (at the N, S, E and W monitoring equipment, not including the background values) were significantly less than concentrations that were seen in a study done in 2006 along the Front Range. For this monitor, the SNMOC, unknown and TNMOC average values were 249, 111 and 358 ppbC, while in the 2006 study they were 371, 542 and 913 ppbC, respectively. The Front Range study was not performed under the same conditions as this study (sampling was not done directly around well pads), and is more indicative of background concentrations than site-specific concentrations. One interesting note, however, is seen in the percentage of unknown to known compounds. The Front Range unknown percentage was nearly double that of Site B, with values of 59% and 31%, respectively. The difference is likely due to the different components in the natural gas fields being tapped, and that the Front Range area includes a number of more urban-related components.

In summary, the average of the particulate concentrations recorded around the well pad (9.3 $\mu g/m^3$) was much lower than the EPA's recommended 24 hour maximum exposure value (35 $\mu g/m^3$), and appears to be fairly uniform for this site when compared to the value obtained by the background monitor (8.2 $\mu g/m^3$), and the relative percent difference of 13% between the two values. The duplicate samples taken, however, showed a relative percent difference of 42% between the samplers. The 27-hour average VOC concentration of 25 ppbv that was observed appears to be highly dependent on the local meteorological conditions around the site, meaning that if the wind was not blowing in a direction that pushed the VOC plume toward the monitor concentrations were not recorded. The one-minute maximum VOC concentration recorded was 1,950 ppbv. The primary wind direction around the site was from the west to west-northwest with an average wind speed of 1.8 mph. The NMOC concentrations also seem to be rather uniform for this site, as the average of the concentrations around the well pad is similar to the values recorded by the background monitor. The well pad averages for SNMOCs, unknowns and TNMOCs were 247, 118, and 365 ppbC, respectively, while the background monitor concentrations were 251, 73 and 324, respectively. This gives an average relative percent difference of 20% between the background and well pad monitors. The duplicate NMOC samples showed some agreement with an average relative percent difference of 25% between the samplers.

5.1.2 SITE D

The placement of the samplers around drilling Site D is seen in Figure 11. The orange colored balloons again indicate the sampling locations, while well locations are marked by the presence of the oil rig symbols. The background monitor was located approximately 0.4 miles southwest of the well pad site. The other four sampling areas were located in the approximate cardinal directions surrounding the pad. As with Site B, the figure indicates that the land is primarily an agricultural area, but has been partially converted to a drilling area. The longitude and latitude coordinates for each of the sampling monitors shown, in addition to the type of instruments installed at each site, is included in Table 7. For this well pad, the duplicate samplers were located at the east site again, along with the VOC and met instruments. Producing natural gas wells are all around Site D, but cannot be seen in the picture due to its scale. To the N, NW, SW, S and SE there are dozens of wells currently in production. They are all within a half-mile radius from the well pad.

Figure 11. Site D Sampling Locations and Surrounding Wells

Table 7. Site D Instrument Locations

Site	Sampling Location	Latitude	Longitude	Instrument Types
D	North (N)	39.508667°	-107.685367°	NMOC, $PM_{2.5}$
	South (S)	39.507183°	-107.685117°	NMOC, $PM_{2.5}$
	East (E)	39.507900°	-107.684050°	NMOC(x2), VOC, MET, $PM_{2.5}$(x2)
	West (W)	39.508200°	-107.686167°	NMOC, $PM_{2.5}$
	Background (C)	39.502817°	-107.688483°	NMOC, $PM_{2.5}$

The particulate matter concentrations obtained for Site D are shown in Figure 12. All samples were taken for 24-hours. Unlike the duplicate samples at Site B, this site's duplicates exhibited very similar concentrations with values of 8.0 and 7.6 $\mu g/m^3$, and an RPD of 4.5%. The highest concentration was recorded at the north sampler, with a value of 11.4 $\mu g/m^3$. The background site did not record the lowest value again. The south site had the lowest concentration at 5.2 $\mu g/m^3$ and the background site value was 5.5 $\mu g/m^3$, giving an RPD of 5.6%. The average concentration over the well pad was 7.8 $\mu g/m^3$, which is larger than the concentration seen at the background site, and figures into a 35% RPD between the two values. At Site D it would seem that the particulate concentrations around the well pad are slightly higher than those obtained at the background monitor.

The high particulate concentration at the north site appears to be due to the fact that the wind was primarily out of a southerly direction. The majority of the wind came from the SSE, with the SE and WSW directions contributing as well. A primarily southern wind would push any of the particulates generated during the drilling process to the north to be captured at that sampler. The slightly elevated concentrations seen at the east site lend further credence to this, since there were westerly winds recorded as well.

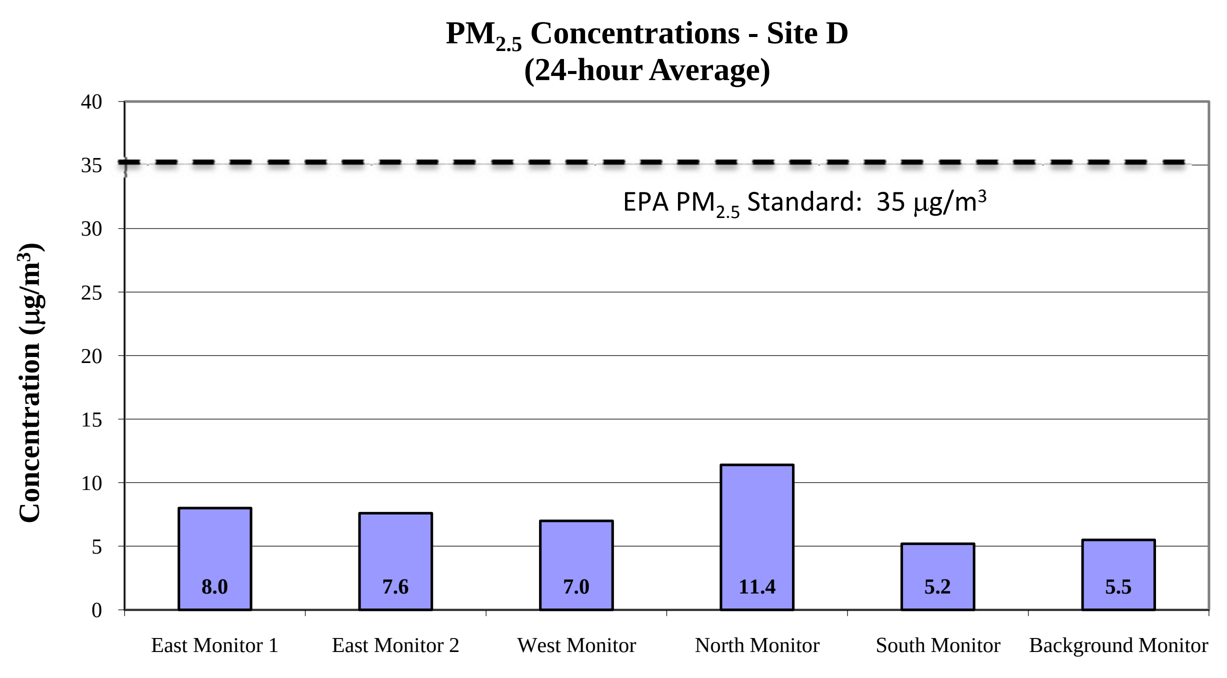


Figure 12. $PM_{2.5}$ Concentration Data for Site D

The wind direction and concentration detection frequencies are seen in Figure 13. It shows that when there was a VOC concentration detected with a simultaneous wind speed, the wind was out of the E to SSE direction. Nearly 35% of the time when the wind was from the SSE there was a simultaneous VOC concentration detected. When there was a measured wind speed and no VOC concentration detected, the wind was primarily from a westerly direction. For the approximately 40% of the time that the wind was from the W and WSW there were no VOC concentrations detected. At this time the average wind speed was 9.4 mph. The wind and concentration correlations are perhaps better illustrated in Figure 14 and Figure 15

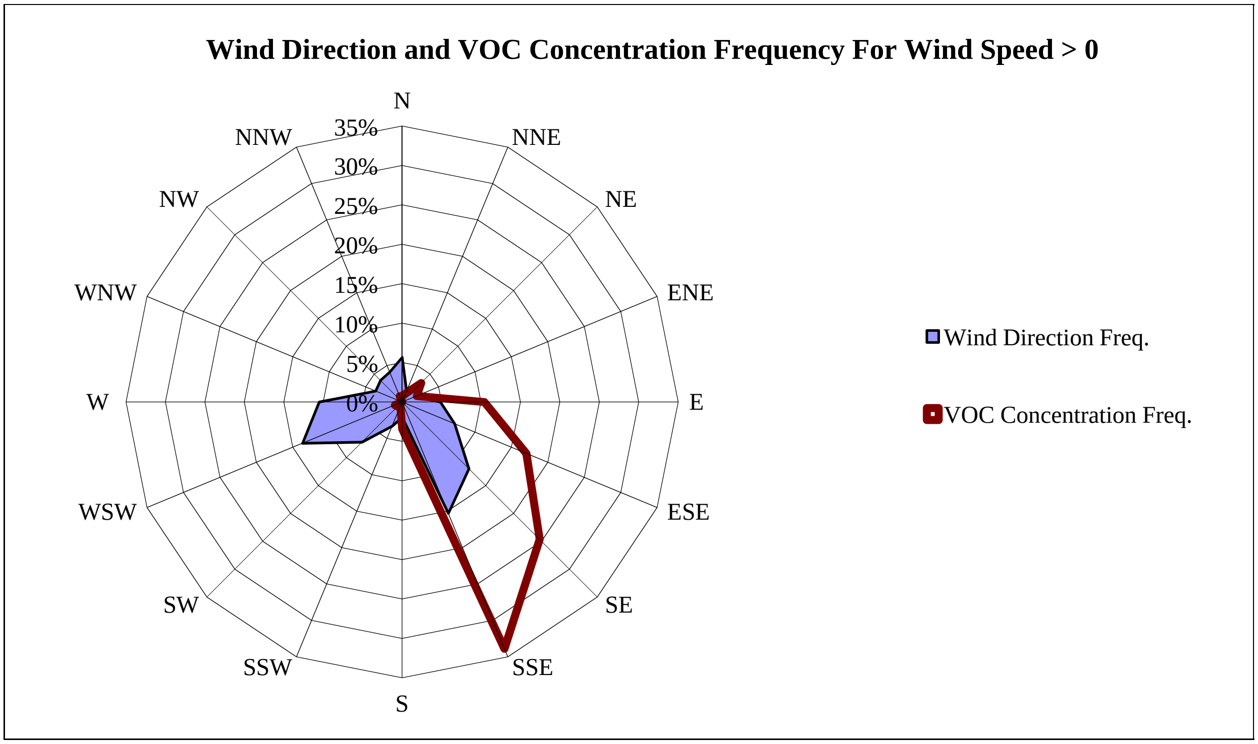


Figure 13. Wind Direction and Concentration Detection Frequencies for Site D

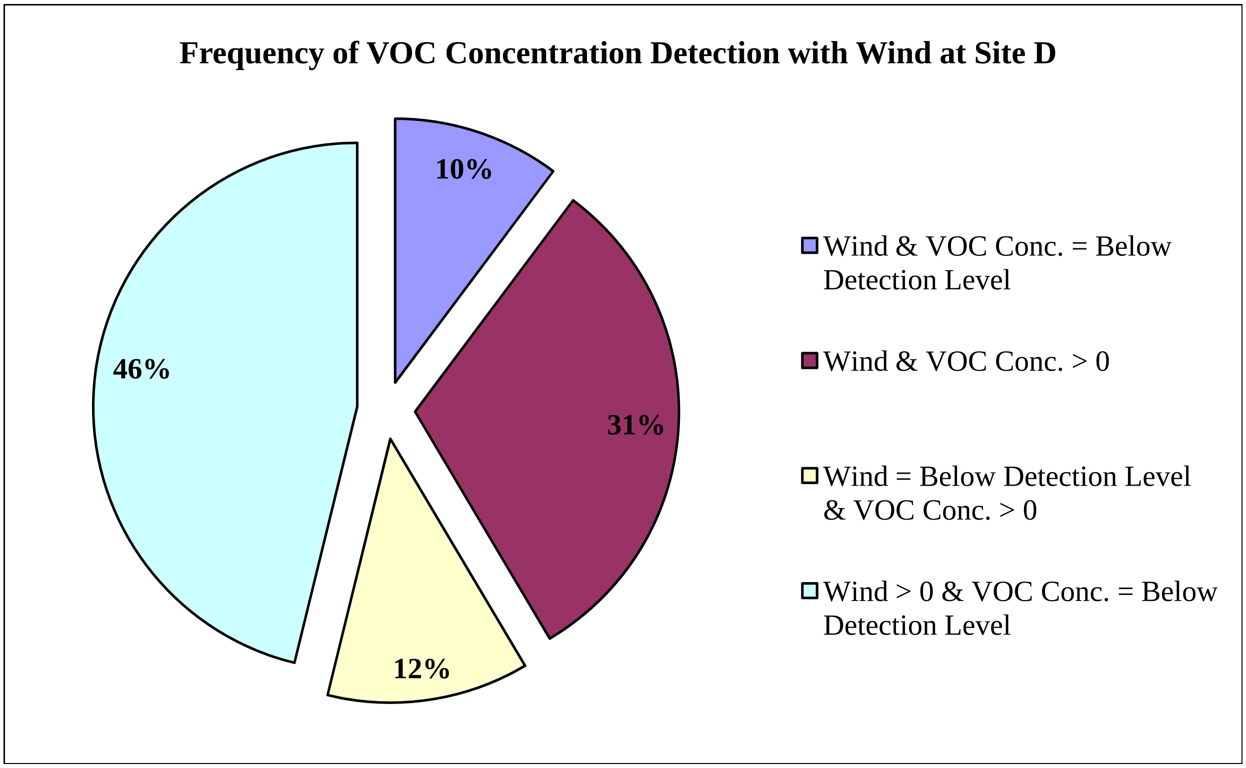


Figure 14. Frequency of VOC Concentration Detection with Wind for Site D

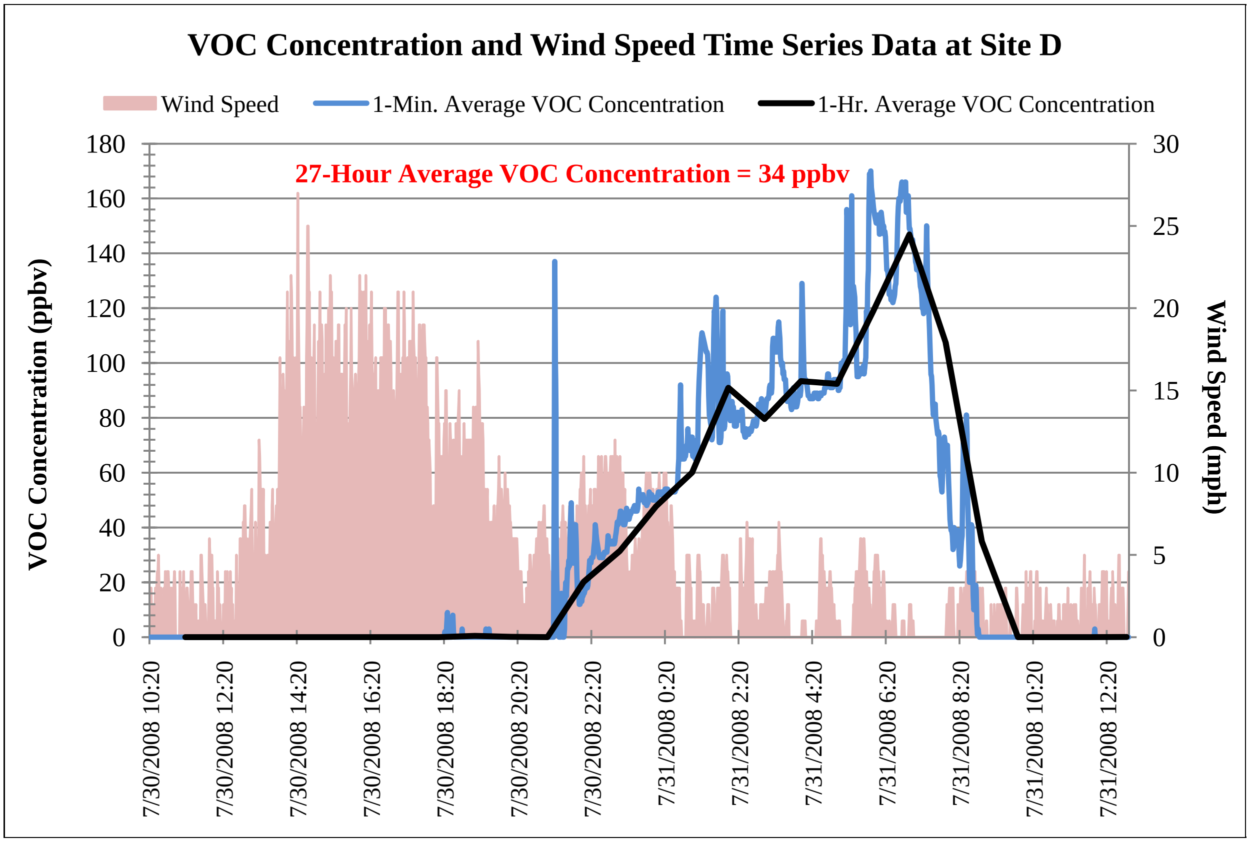


Figure 15. Time Series Data for Wind Speed and VOC Concentration at Site D

Table 8. Maximum and Average VOC Concentrations

Maximum VOC Concentration (taken from 1 minute avgs.)	**Average VOC Concentration (averaged over 27 hours)**
170 ppbv	34 ppbv

Figure 14 shows the frequency with which there was a VOC concentration detected at the same time a measurable wind speed was recorded. Only 10% of the time was there no wind or VOC concentrations detected. For 31% of the time there was both wind and a concentration detected, 12% of the time there was no wind and a concentration, and 17% of the time there was wind but no concentrations recorded. For slightly more than half of the sampling time there was no VOC concentration data recorded. This is likely due to the very large wind speeds seen during those times. The average wind speed from 10:00 to 21:00 on 7/30/2008 was 9.4 mph, while from 21:00 to 13:00 the following day the wind speed averaged 2.8 mph. Figure 15 shows that once the wind speeds died down to around 10 mph or less the VOC concentrations rose significantly. The average VOC concentration was 0.1 ppbv from 10:00 to 21:00 on 7/30/2008, but was 57 ppbv from 21:00 to 08:00. For the entire sampling period of 27 hours, the average wind speed was 5.4 mph and the average VOC concentration was 34 ppbv. The peak VOC concentration seen was 170 ppbv. This occurred several times between 05:00 and 07:00 on 7/31/2008. The correlation between decreased wind speeds and increased VOC concentrations is well illustrated in this figure.

The NMOC sampling took place from 7/30/2008 at approximately 11:00, to 7/31/2008 at approximately 13:00, for an overall sampling period of 26 hours. According to the well pad site map, the production equipment and tanks were located to the south and west of the eastern monitors. A primarily SE wind would push any pollutants towards the northern and western monitors, but they did not see the elevated NMOC values. There was also wind from a westerly direction, however, and this would have pushed the pollutant plume toward the eastern monitors. The secondary eastern monitor did indicate elevated TNMOC concentrations, but the primary monitor did not. In fact, the concentration at the secondary monitor is nearly four times larger than that at the primary monitor. This can be seen in Figure 16.

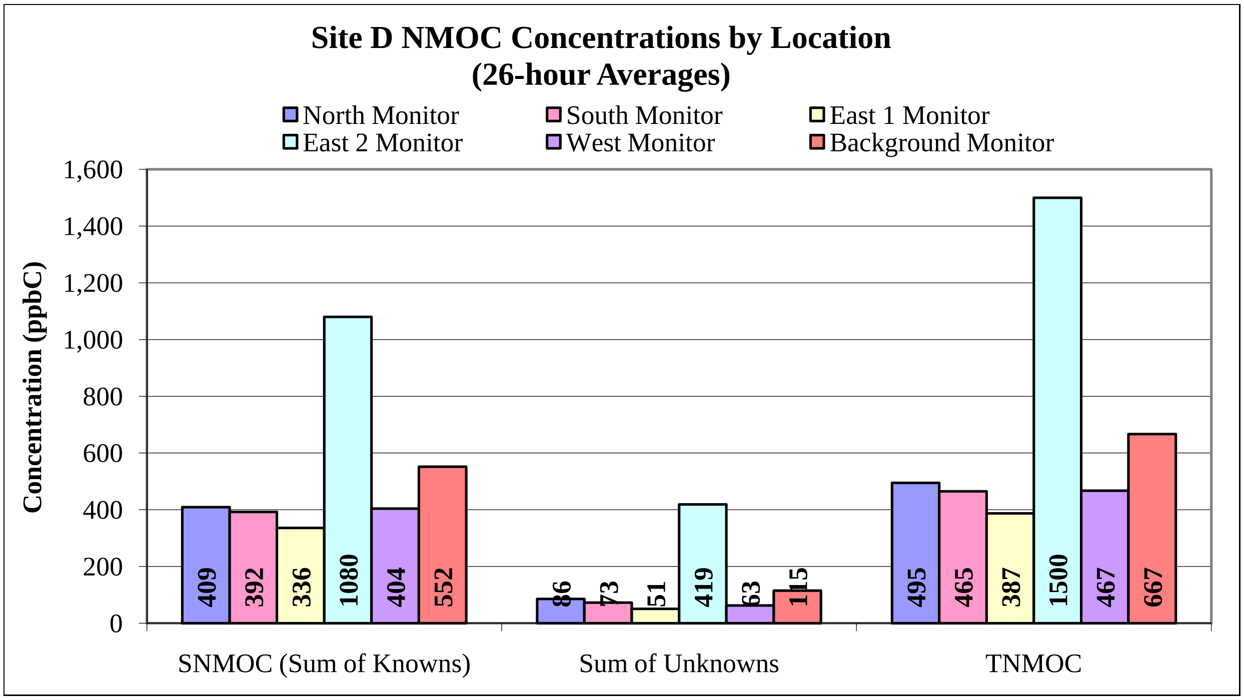


Figure 16. Site D NMOC Concentrations by Monitor Location

The average SNMOC concentration for the well pad is 529 ppbC, while the TNMOC average is 664 ppbC. The average percentage of unknowns to total knowns is 17%, with a value of 135 ppbC. The averages were quite similar to each other, with RPD values of 4, 16 and 0.5% respectively, as can be seen in Table 9. The north, south, primary east and west monitors all appear to have relatively similar concentrations, ranging between 336 and 409 ppbC. The background site, however, exhibited the second highest SNMOC, TNMOC and unknown concentrations. It is likely that the background site's proximity to nearby producing wells affected the background results obtained. Only the secondary east site and the background site saw compounds with concentrations large enough to be reported as estimates. At the secondary east site the isopentane and n-butane concentrations were estimated at 33 ppbv each, while the ethane concentration at the background site was estimated to be around 60 ppbv.

Table 9. Well Pad Avg. and Background Monitor NMOC Concentrations and RPD

	Well Pad Avg. Concentration (26-hour) ppbC	Background Monitor Concentration (26-hour) ppbC	RPD %
SNMOC	529	552	4
Sum of Unknowns	135	115	16
TNMOC	664	667	0.5

The values obtained at this well pad show higher recorded SNMOC concentrations than those seen during the 2006 Front Range study. The TNMOC and unknown concentrations were lower though. The 2006 SNMOC, unknown and TNMOC concentrations were 371, 542 and 913 ppbC. For this study the averages were 529, 135 and 664 ppb, respectively. It appears as though the organic pollutants were better characterized for this study, as opposed to the 2006 study. There was an average of 17% non-detectable compounds for the entire pad, as compared to the 58% seen in 2006. The differences in compounds detected could also be due to differences in the oil/natural gas reserves being tapped, or urban influences.

The highest speciated NMOC concentrations recorded at the north site were again due to ethane and propane, with values of 47 and 21 ppbv, respectively. Of the 78 compounds tested for, 55 were detected, 22 were not detected or had concentrations below the MDL, and one (isobutene/1-butene) was not reportable due to a peak splitting issue. Aside from the ethane and propane concentrations, all other detected concentrations were less than 10 ppbv. The SNMOC concentration was approximately 400 ppbC, while the TNMOC concentration was near 500 ppbv. This gives an unknown percentage of 17%, which is in line with the percentages obtained at the other sites, with the notable exception of the secondary east site.

As with the north site, the high concentrations seen at the south site were again due to ethane (47 ppbv) and propane (24 ppbv). The remainder of the 48 detected compounds all had values less than 10 ppbv. There were 30 non-detectable/non-reportable compounds. The averages obtained for SNMOC (390 ppbC), unknowns (70 ppbC) and TNMOC (460 ppbC) were all considerably lower than the 2006 Front Range study. The ethane and propane concentrations recorded at each monitor can be seen in the figure below.

As was previously mentioned, the primary and secondary eastern sites observed vastly different NMOC concentrations, with the secondary sight showing values nearly four times higher than the primary site. At this time, the cause for this anomaly is unknown, as there are no drilling rig activity logs or notes to refer to for this site. Table 10 lists the concentrations of the detected compounds in each of the duplicate samples, and the relative percent difference between the dataset. The average RPD of the dataset is 109%. The primary site saw ethane and propane concentrations of approximately 40 and 20 ppbv, which were the highest of the speciated NMOCs recorded at this monitor. The remaining 53 detected compounds had concentrations values less than 10 ppbv. The secondary site also had high ethane and propane concentrations at 32 and 16 ppbv. They were not so high that they were estimates like the isopentane and n-pentane values of 33 ppbv. This is the first and only time where there are estimated concentrations reported that are not ethane and propane. For the primary site there were 25 non-detected/non-reportable compounds, and for the secondary site there were only 12—in addition to the two estimates and the co-eluting peak that came through with the isobutene.

Table 10. Duplicate NMOC Sample Concentrations and RPD

ANALYTE	RESULT 1 (ppbC)	RESULT 2 (ppbC)	RPD (%)
1,2,4-Trimethylbenzene	0.734	5.05	149
1,3,5-Trimethylbenzene	0.56	0.909	48
1-Dodecene	0.357	1.23	110
1-Heptene	1.28	1.3	2
1-Hexene	0.176	0.214	19
1-Pentene	0.183	0.671	114
2,2,3-Trimethylpentane	0.286	1.41	133
2,2-Dimethylbutane	0.863	2.65	102
2,3,4-Trimethylpentane	0.149	1.98	172
2,3-Dimethylbutane	1.74	3.46	66
2,3-Dimethylpentane	0.829	2.74	107
2,4-Dimethylpentane	0.629	1.06	51
2-Methylheptane	1.36	2.21	48
2-Methylhexane	2.45	4.48	59
2-Methylpentane	7.51	13.4	56
3-Methylheptane	1.08	1.98	59
3-Methylhexane	2.22	6.56	99
3-Methylpentane	4.22	7.51	56
4-Methyl-1-pentene	0.264	2.67	164
Acetylene	0.761	9.14	169
a-Pinene	0.424	3.01	151
Benzene	1.79	15.5	159
b-Pinene	0.299	1.61	137
cis-2-Butene	0.138	0.428	102
cis-2-Pentene	0.08	0.711	160

ANALYTE	RESULT 1 (ppbC)	RESULT 2 (ppbC)	RPD (%)
Cyclohexane	5.45	53.6	163
Cyclopentane	0.963	2.33	83
Cyclopentene	0.326	0.493	41
Ethane	79.9	63.4	23
Ethylbenzene	0.477	7.61	176
Ethylene	1.1	8.9	156
Isobutane	25.1	67.5	92
Isopentane	27.7	166	143
Isoprene	1.02	2.42	81
m-Diethylbenzene	0.53	3.78	151
Methylcyclohexane	11	9.92	10
Methylcyclopentane	4.13	6.72	48
m-Ethyltoluene	0.509	2.76	138
m-Xylene/p-Xylene	3.08	19.7	146
n-Butane	28.7	27.6	4
n-Decane	1.37	32.8	184
n-Dodecane	1.3	83.6	194
n-Heptane	4.71	7.34	44
n-Hexane	8.45	10.7	23
n-Nonane	1.72	3.5	68
n-Octane	3.56	4.36	20
n-Pentane	15.4	161	165
n-Propylbenzene	0.23	1.1	131
n-Tridecane	0.648	9.08	173
n-Undecane	1.58	100	194
o-Ethyltoluene	0.361	2.48	149
o-Xylene	0.621	6.99	167
p-Diethylbenzene	0.213	0.689	106
p-Ethyltoluene	0.341	1.62	130
Propane	61.2	48.1	24
Propylene	0.692	3.7	137
SNMOC (Sum of Knowns)	334	1100	107
Sum of Unknowns	48.2	423	159
TNMOC	382	1530	120
Toluene	4.51	65.6	174
trans-2-Butene	0.145	0.907	145
trans-2-Pentene	0.085	1.72	181

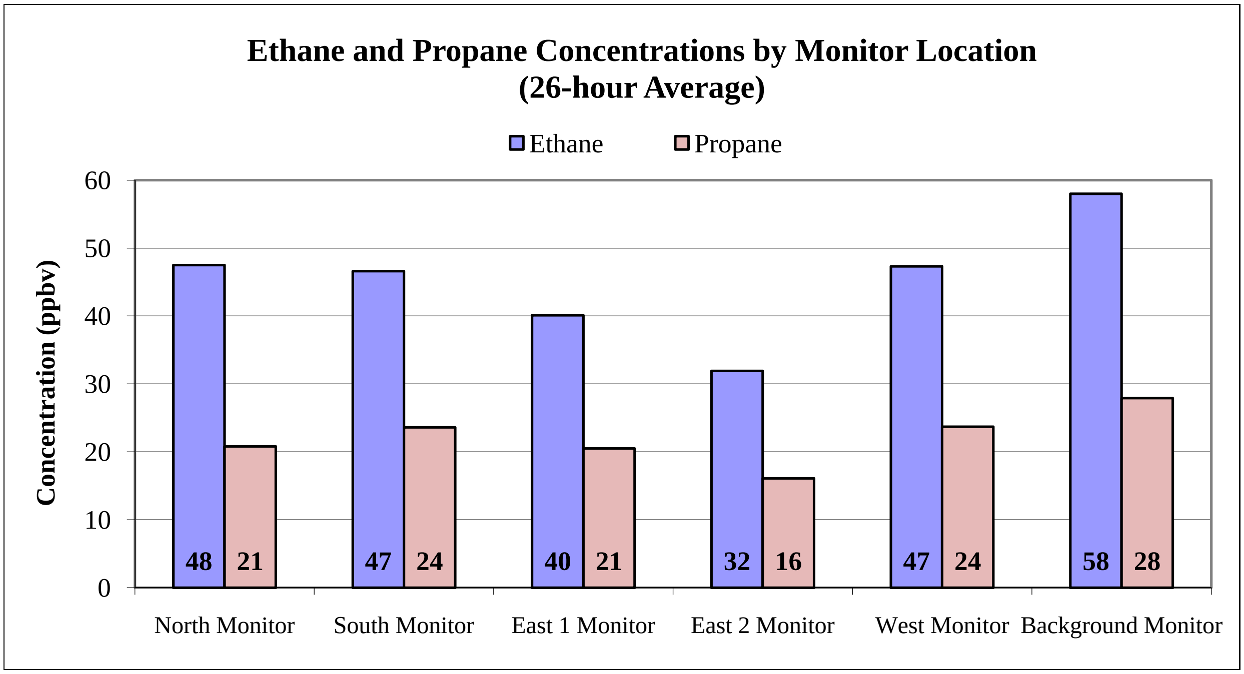


Figure 17. Site D Ethane and Propane Concentrations by Monitor Location

The western site saw high ethane and propane concentrations at 47 and 24 ppbv. The ethane and propane concentrations at the remaining monitors are shown in Figure 17. All of the remaining 49 compounds were less than 10 ppbv. There were 29 non-detected/non-reportable compounds. This site had one of the lowest unknown percentages at 13%. It is surprising that with a primarily SE wind at this site there were not higher concentrations seen here. The site map indicates that the production tanks and facilities being located in a southeasterly direction from the monitor.

The background site detected higher "background" concentrations than the actual drilling monitors saw. The ethane concentration here was estimated at 59 ppbv, while the propane was listed as 27 ppbv. All of the remaining detected compounds had concentrations that were less than 10 ppbv. There were 21 non-detectable/non-reportable compounds.

In summary, the average of the particulate concentrations recorded around the well pad (7.8 $\mu g/m^3$) was much lower than the EPA's recommended 24 hour maximum exposure value (35 $\mu g/m^3$), and appears to be somewhat uniform for this site when compared to the value obtained by the background monitor (5.5 $\mu g/m^3$) and the relative percent difference of 35% between the two values. The duplicate samples taken show good agreement with a relative percent difference of 5% between the samplers. The 27-hour average VOC concentration of 34 ppbv that was observed appears to be highly dependent on the local meteorological conditions around the site, meaning that if the wind was not blowing in a direction that pushed the VOC plume toward the monitor concentrations were not recorded. The one-minute maximum VOC concentration observed was 170 ppbv. The primary wind direction at this site was from a southerly direction, with an average speed of 5.4 mph. The NMOC concentrations also seem to be rather uniform for this site, as the average of the concentrations around the well pad is similar to the values recorded by the background monitor. The well pad averages for SNMOCs, unknowns and TNMOCs were 529, 135, and 664 ppbC, respectively, while the background monitor concentrations were 552, 115 and 667, respectively. This gives an average relative percent difference of 7% between the background and well pad monitors. The duplicate NMOC samples showed little agreement with an average relative percent difference of 127% between the samplers.

5.1.3 SITE F

Site F was located approximately two miles southeast of the Rifle exit on Interstate 70. The well pad is situated on the edge of a small canyon leading down from Grass Mesa. It is surrounded by dozens of actively producing wells, the majority of which are to the south and east of this pad. The southern sampling location housed the duplicate NMOC and $PM_{2.5}$ samplers, the met station and the continuous VOC analyzer. According to the well pad layout diagram, the southern site was 114 yards south of the drilling rig. The west, north and east sites were 114, 61 and 24 yards from the rig, respectively. The background site was placed approximately ¾ of a mile to the southwest of the pad, and was slightly higher in elevation. Though they are not indicated in the pad diagram, there are also several other producing wells that were approximately ¾ of a mile to the southwest of the background site. The diagram also indicates the location of the production tank battery as being in the southeast corner of the pad, but states that it was to be moved to the northeast corner of the pad.

Figure 18 shows the locations of the sampling sites around the well pad. In addition, several other producing wells are marked, as they were in close proximity to the sampling areas. The exact sampling site coordinates and the associated instruments that were located at each are listed in Table 11.

Figure 18. Site F Sampling Locations and Surrounding Wells

Table 11. Site F Instrument Locations

Site	Sampling Location	Latitude	Longitude	Instrument Types
F	North (N)	39.504983°	-107.744850°	NMOC, $PM_{2.5}$
	South (S)	39.503750°	-107.745017°	NMOC(x2), VOC, MET, $PM_{2.5}$(x2)
	East (E)	39.504383°	-107.744533°	NMOC, $PM_{2.5}$
	West (W)	39.504417°	-107.745483°	NMOC, $PM_{2.5}$
	Background (C)	39.496133°	-107.753167°	NMOC, $PM_{2.5}$

Figure 19 shows the particulate concentrations seen at Site F. All samples were taken over a 24-hour period. The particulate concentrations seen at this drilling site were in the same 7 to 12 micrograms per cubic meter range that was seen at the previous two drilling sites. The average concentration over the pad area was 8.0 $\mu g/m^3$, while at the background site it was 5.0 $\mu g/m^3$. The background concentration is in line with what was seen at Site D (5.5 $\mu g/m^3$), but is less than what was seen at Site B (8.2 $\mu g/m^3$). The duplicate samplers at the southern site recorded very similar results at 8.0 and 7.8 $\mu g/m^3$, respectively, giving a relative percent difference of 2.5%. The northern site had the highest of the particulate concentrations at 10.5 $\mu g/m^3$. The western site had the lowest particulate concentration of the well pad sites.

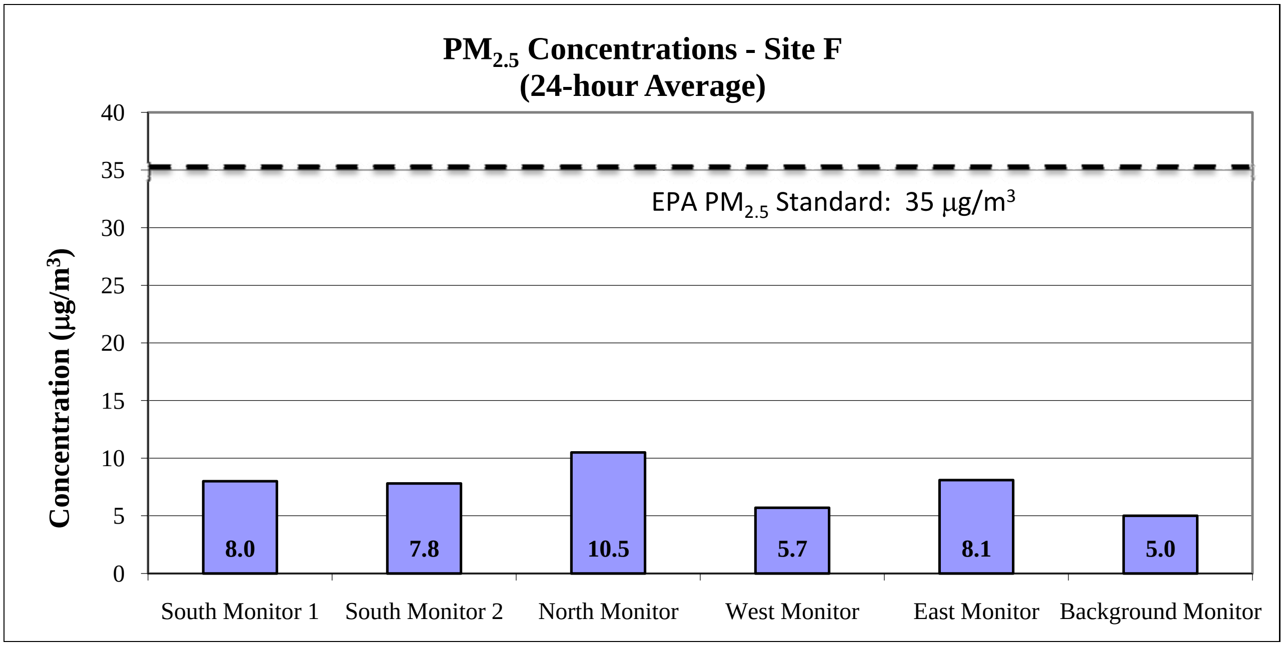


Figure 19. $PM_{2.5}$ Concentrations at Site F

According to Figure 20, the primary wind direction was from the SSW. However, there was a large percentage of wind from the NNW as well. When the wind was from the NNW, a VOC concentration was detected more frequently than from any other wind direction. The SSW majority wind direction makes sense when considering the location of the pad. The canyon it was situated along runs from the NE to the SW, and would funnel any wind in that direction. The NNW wind direction is likely due to the fact that the leading edge of the mesa ends at a point that is in a northwesterly direction from the meteorological station. The larger particulate concentrations seen at the north, east and south sites are a clear indication of the effects of the S, W and N winds.

During this study, there was no wind or VOC concentration detected 36% of the time. Fifteen percent of the time there was both a measured wind speed and a VOC concentration detected; 1% there was no wind and VOC concentration detection; and 49% of the time there was wind, but no VOC detection. This breakdown can be seen in Figure 21 below. At this site, VOC concentrations were detected a total of only 16% of the time. This is a significantly smaller percentage than what was seen at Sites B and D. Site B saw a VOC concentration 34% of the time, while Site D saw one 43% of the time. This significant difference is due to the primary wind direction being from the SSW. This pushed any of the pollutants away from the southern VOC monitor, which is clearly evident in Figure 20.

According to the site diagram provided by the drilling company, the northern monitors were placed 61 yards north of the drilling rig. This accounts for the larger particulate concentrations seen at that sampling location. The eastern monitors were 24 yards east of the rig and to the north of the production tanks and facilities. The southern monitor was 114 yards south of the rig, and was not near any equipment according to the diagram. The western monitor was 84 yards west of the rig, and was placed just behind some project trailers that were on the site.

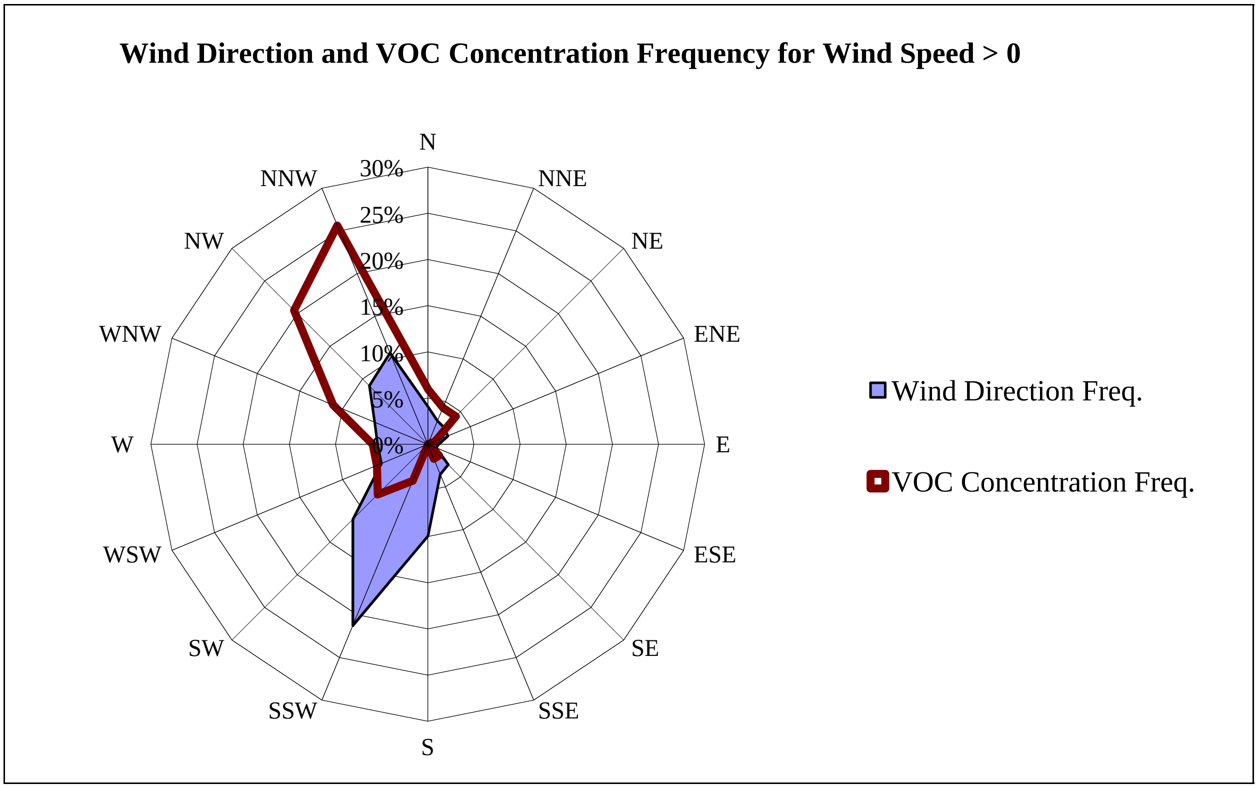


Figure 20. Wind Direction and Concentration Frequencies at Site F

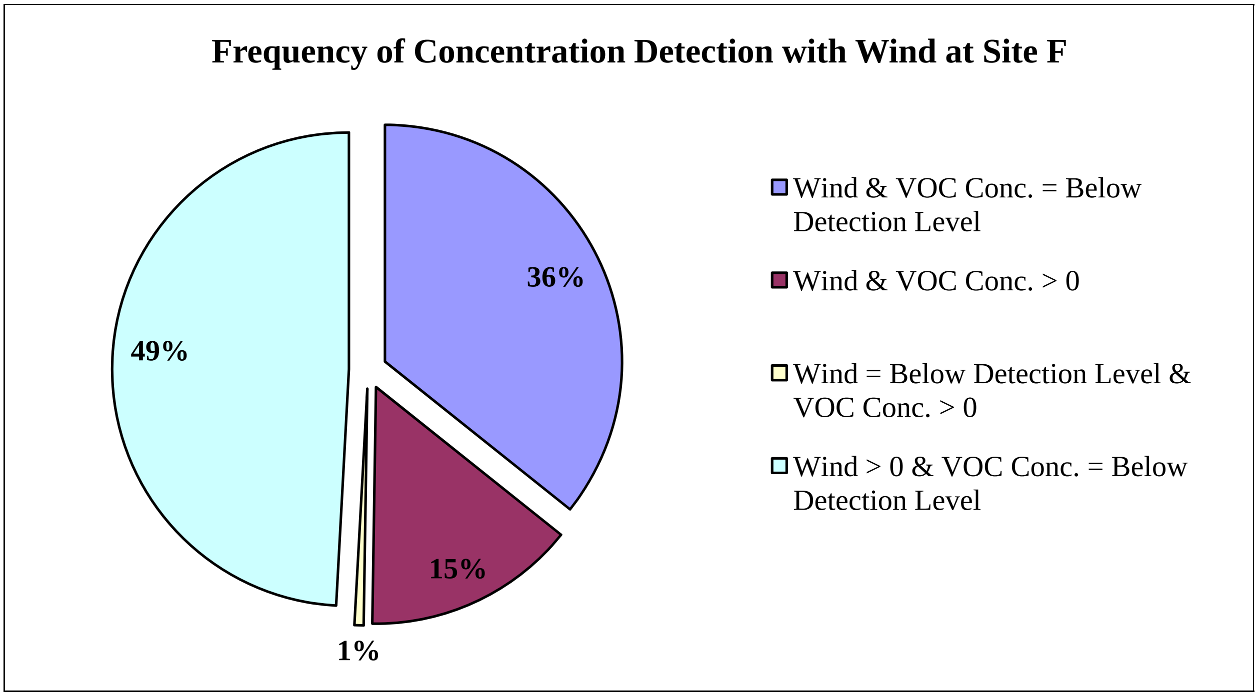


Figure 21. Frequency of VOC Concentration Detection with Wind for Site F

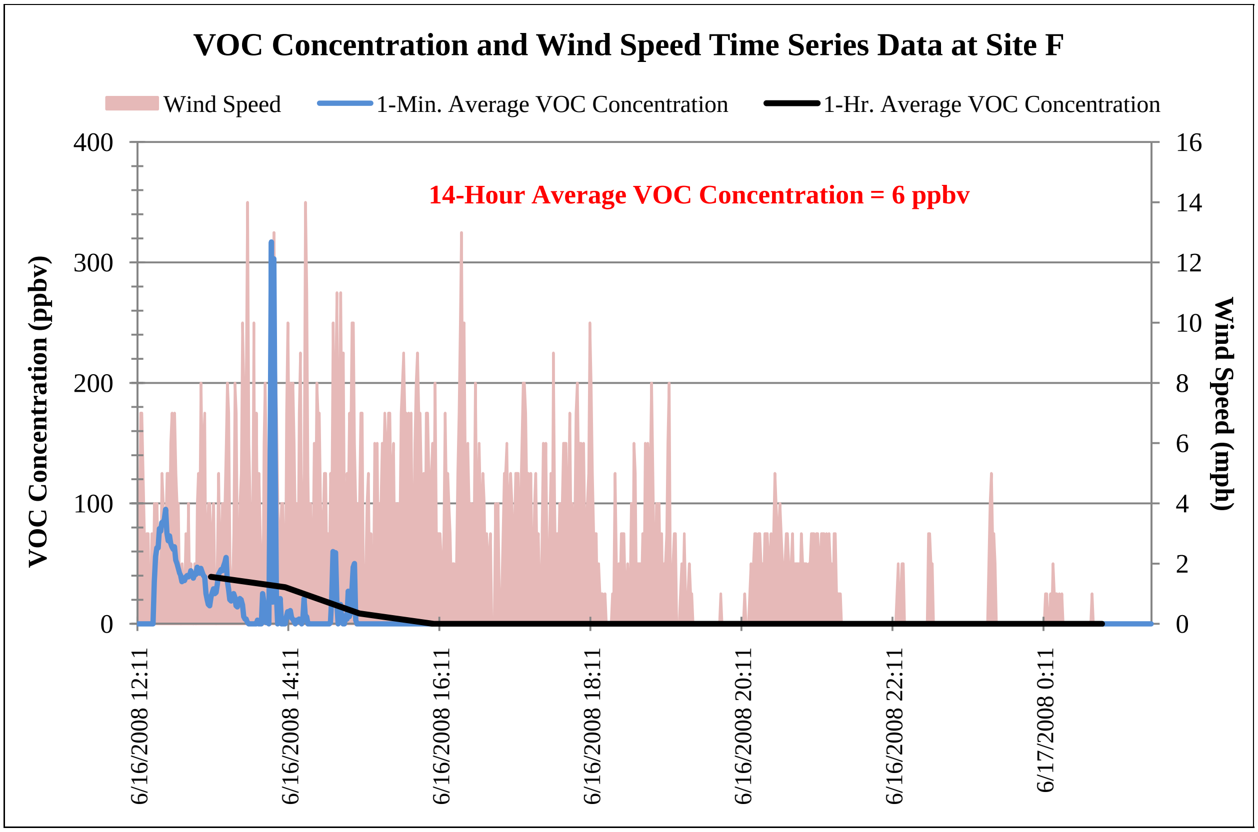


Figure 22. Time Series Data of VOC Concentration and Wind Speed at Site F

Figure 22 shows the time series data for the wind speed and VOC concentrations. The sampler was run for only 14 hours at this monitoring location. The reason for this is unknown, but may have been due to a battery failure in the instrument. There was one three hour burst of VOC activity from approximately 12:15 to approximately 15:00 on the afternoon of 6/16/2008. During that time, there were concentration spikes to near 300 ppbv. According to the site notes, between 13:30 and 15:00 on 6/16/2008 there was an equipment truck that arrived on site, a forklift that unloaded that truck, a truck unloading cement into the cutting pit, and a backhoe digging up the pit that were all in operation. The burst of VOC activity seen during this time period does seem to correlate with the arrival of the trucks and the subsequent activity. It seems likely that the VOC emissions seen here are due to the diesel exhaust from the trucks, but it is uncertain, as there are no additional notes stating any of the drilling activities for this same time period. The maximum and average VOC concentrations observed during the sampling period are listed in Table 12. The figures above indicate that VOC concentrations were most frequently detected when the wind was from the NNW to NW direction. The average wind speed during the time period that VOC concentrations were detected was approximately 4.5 mph. Throughout the time when both the met and VOC samplers were running the average wind speed was 2.4 mph. That was also the average for the entire time the met station was in operation. The average VOC concentrations during these times were 26 and 6 ppbv, respectively. The very low average VOC concentration is likely due to the fact that the VOC sampler was in operation for only 14 hours.

Table 12. Maximum and Average VOC Concentrations

Maximum VOC Concentration (taken from 1 minute avgs.)	Average VOC Concentration (14-hour)
317 ppbv	6 ppbv

The NMOC samples at Site F were started on 6/16/2008 at roughly 14:00, and ran until 6/17/2008 at approximately 15:00, for a total sampling time of approximately 25 hours. Figure 23 shows the NMOC concentrations recorded at each of the sampling locations around Site F. The southern primary and secondary sites showed the highest TNMOC and SNMOC concentrations at this pad, with values of 419 and 404 ppbC (TNMOC) and 348 and 343 ppbC (SNMOC), but were not near any production equipment. These samplers averaged a 16%

unknown concentration, relative to the concentration of TNMOCs. The average percentage of unknowns recorded at this site was 22%. Most of the sites hovered around the 14 to 18% mark, but the eastern site had a 22% value and the western site had a 46% value, which is quite intriguing considering that site had the lowest values of all the sites, and was placed behind a row of three project trailers. The average SNMOC, unknown and TNMOC concentrations for the pad were 273, 63 and 336 ppbC, respectively. These values are all higher than the values recorded at the background monitor. A summary of the values and their relative percent differences is listed in Table 13.

The background site had the second lowest TNMOC and SNMOC concentrations (behind the western site), and the lowest unknown concentration. The two highest speciated concentrations seen at the background site were again those of ethane and propane, with values of 27 and 11 ppbv, respectively. Of the 78 compounds being analyzed for, 27 were not detectable or reportable at this location. As was previously mentioned, this site was located approximately ¾ of a mile to the northeast of several actively producing wells. Higher concentrations at the background site are likely due to the proximity of other actively producing wells, and the fact that the wind observed by the western monitors would have blown what little pollutants that made it past the trailers away.

The western site had very low ethane and propane concentrations with values of 6 and 3 ppbv, respectively. These values are the two lowest recorded at any of the sampling locations on this site. Figure 24 shows a graph of the propane and ethane concentrations recorded at each site. It clearly indicates how much lower the ethane and propane values were at the west site as opposed to the other sites. Again, this is due to the winds blowing the pollutants away from the western monitor. In addition to the low concentrations at this location, there was also a very large number of non-detect/non-reportable compounds—in the amount of 43.

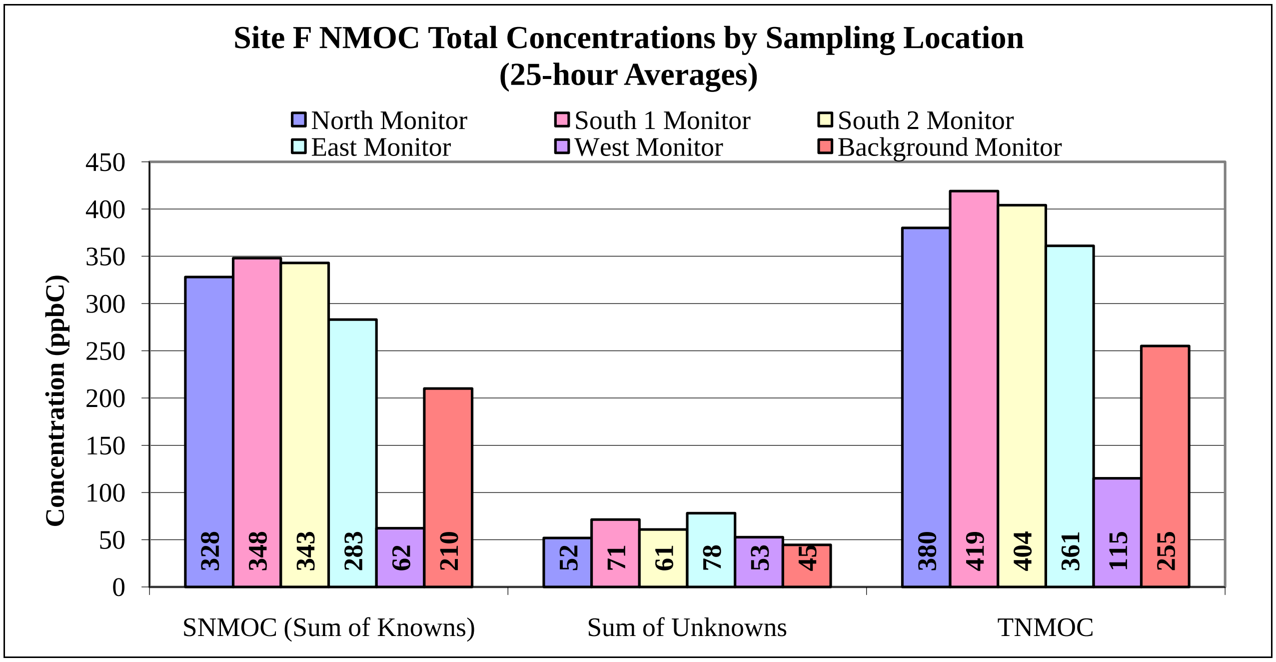


Figure 23. Site F NMOC Concentrations by Sampling Location

Table 13. Well Pad Avg. and Background Monitor Concentrations and RPD

	Well Pad Avg. Concentration (25-hour avg.) ppbC	Background Monitor Concentration (25-hour avg.) ppbC	RPD %
SNMOC	273	210	26
Sum of Unknowns	63	45	33
TNMOC	336	255	27

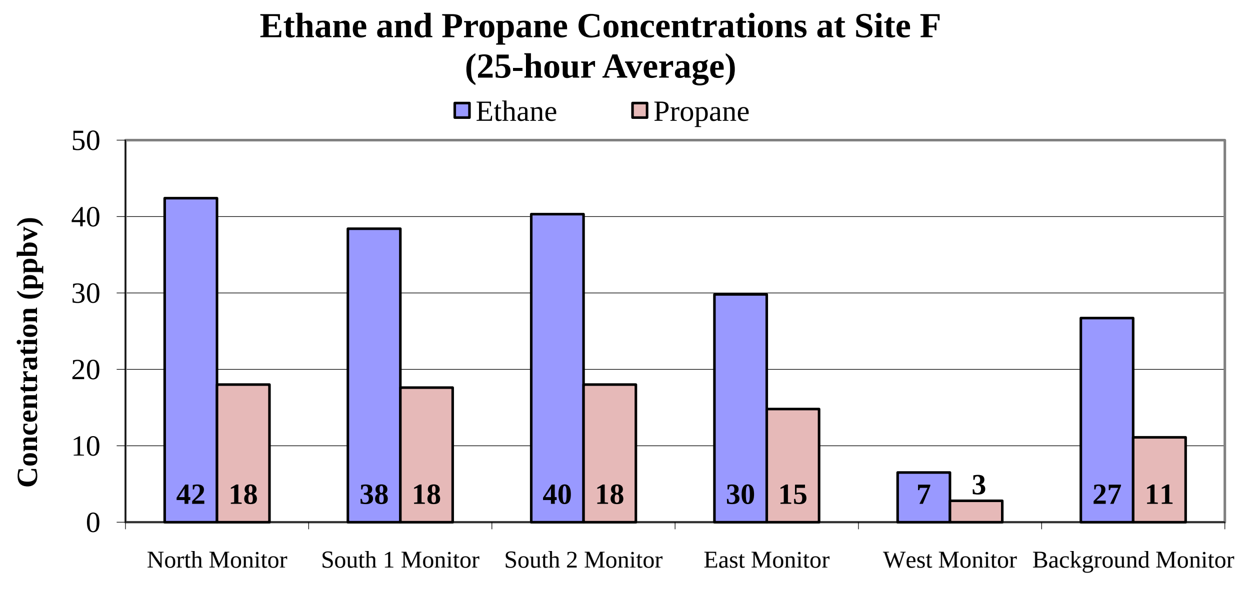


Figure 24. Site F Ethane and Propane Concentrations by Sampling Location

The eastern sampling site had an ethane concentration of approximately 30 ppbv, and a propane concentration of approximately 15 ppbv. It had the fourth highest concentrations of unknowns, TNMOCs and SNMOCs. There were 27 non-detectable/non-reportable compounds of the 78 that were analyzed for. While the particulate monitors at the northern and eastern sites recorded the highest and second highest concentrations due to the primarily southwesterly wind, this was not the case for the NMOC monitors at those sites.

The north site did have the highest ethane and propane concentrations, with values of 42 and 18 ppbv, respectively. It did not, however, have the highest concentration values for SNMOCs, unknowns or TNMOCs. It had the second highest of the sampling locations at this site, when the data from the southern monitors was averaged. There were 22 non-detectable/non-reportable compounds. The particulate and NMOC samplers were run for approximately the same amount of time, so it's possible that location of the NMOC source, combined with the compounds' volatility, may have prevented the northern site from seeing the highest concentrations.

The southern site saw both the highest ethane and propane concentrations (39 and 18 ppbv), as well as the highest SNMOC and TNMOC concentrations (averages of 346 and 412 ppbC). The results for the duplicate samplers here showed very good agreeability with values of 39 and 40 ppbv for ethane and 18 ppbv for propane. There were 23 non-detectable/non-reportable compounds at the primary southern site and 25 at the secondary site. Table 14 lists the duplicate compound results and the relative percent difference between them. The average RPD for all the detected compounds at these monitors is 17%.

Table 14. Duplicate NMOC Sample Concentrations and RPD

ANALYTE	RESULT 1 (ppbC)	RESULT 2 (ppbC)	RPD (%)
1,2,3-Trimethylbenzene	0.198	0.117	51
1,2,4-Trimethylbenzene	0.683	0.612	11
1,3,5-Trimethylbenzene	0.345	0.395	14
1-Dodecene	0.534	0.63	16
1-Heptene	1.44	1.45	1
1-Hexene	0.141	0.101	33
1-Pentene	0.199	0.191	4
2,2,3-Trimethylpentane	0.252	0.241	4
2,2-Dimethylbutane	0.952	0.941	1
2,3,4-Trimethylpentane	0.188	0.132	35

ANALYTE	RESULT 1 (ppbC)	RESULT 2 (ppbC)	RPD (%)
2,3-Dimethylbutane	1.87	1.96	5
2,3-Dimethylpentane	0.892	0.919	3
2,4-Dimethylpentane	0.651	0.653	0
2-Methylheptane	1.31	1.41	7
2-Methylhexane	2.76	2.38	15
2-Methylpentane	8.24	8.9	8
3-Methylheptane	0.975	0.914	6
3-Methylhexane	2.33	2.43	4
3-Methylpentane	4.55	5.12	12
4-Methyl-1-pentene	0.183	0.277	41
Acetylene	0.581	0.495	16
a-Pinene	0.5	0.367	31
Benzene	2.27	2.36	4
cis-2-Hexene	0.51	0.487	5
Cyclohexane	6.37	6.54	3
Cyclopentane	1.17	1.13	3
Cyclopentene	0.331	0.224	39
Ethane	76.2	79.8	5
Ethylbenzene	1.13	0.588	63
Ethylene	1.06	0.814	26
Isobutane	21.4	22	3
Isobutene/1-Butene	13.6	9.73	33
Isopentane	29.9	28.6	4
Isoprene	0.647	0.523	21
m-Diethylbenzene	0.375	0.102	114
Methylcyclohexane	11.7	11.8	1
Methylcyclopentane	5.01	5.36	7
m-Ethyltoluene	0.519	0.442	16
m-Xylene/p-Xylene	5.44	3.5	43
n-Butane	27.2	26.9	1
n-Decane	1.46	1.42	3
n-Dodecane	2.77	1.88	38
n-Heptane	4.96	5.33	7
n-Hexane	9.9	11	11
n-Nonane	1.34	1.32	2
n-Octane	3.12	3.29	5
n-Pentane	18	17.2	5
n-Propylbenzene	0.231	0.207	11
n-Tridecane	0.671	0.52	25
n-Undecane	2.74	2.12	26
o-Ethyltoluene	0.382	0.318	18
o-Xylene	1.23	0.752	48
p-Diethylbenzene	0.228	0.147	43
p-Ethyltoluene	0.65	0.639	2
Propane	52.7	53.5	2
Propylene	0.541	0.446	19

ANALYTE	RESULT 1 (ppbC)	RESULT 2 (ppbC)	RPD (%)
SNMOC (Sum of Knowns)	343	337	2
Sum of Unknowns	68.9	57.9	17
TNMOC	412	395	4
Toluene	6.06	5.7	6
trans-2-Butene	0.136	0.093	38

In summary, the average of the particulate concentrations recorded around the well pad (8.0 $\mu g/m^3$) was much lower than the EPA's recommended 24 hour maximum exposure value (35 $\mu g/m^3$), and appears to be somewhat uniform for this site when compared to the value obtained by the background monitor (5.0 $\mu g/m^3$), and the relative percent difference of 46% between the two values. The duplicate samples taken show good agreement with a relative percent difference of 3% between the samplers. The 14-hour average VOC concentration of 6 ppbv that was observed appears to be highly dependent on the local meteorological conditions around the site, meaning that if the wind was not blowing in a direction that pushed the VOC plume toward the monitor concentrations were not recorded. The one-minute maximum VOC concentration observed was 317 ppbv. The primary wind direction at this site was from the south-southwest, with some wind from the north-northwest, and an average speed of 2.4 mph. The NMOC concentrations also seem to be somewhat uniform for this site, as the average of the concentrations around the well pad is similar to the values recorded by the background monitor. The well pad averages for SNMOCs, unknowns and TNMOCs were 273, 63, and 336 ppbC, respectively, while the background monitor concentrations were 210, 45 and 255, respectively. This gives an average relative percent difference of 29% between the background and well pad monitors. The duplicate NMOC samples showed good agreement with an average relative percent difference of 7% between the samplers.

5.1.4 SITE H

This site was located north of the Parachute/Battlement Mesa area, on the north side of Interstate 70. It was approximately half way up the side of a mesa. There were several other producing wells that were very near the site. The locations of the samplers, and the wells associated with this pad, are illustrated in Figure 25. There is a large number of directionally drilled wells at this pad. The eastern site housed the duplicate NMOC and $PM_{2.5}$ samplers, as well as the met station and continuous VOC analyzer. The VOC samples were taken from approximately 12:45 on 8/13/2008 to approximately 12:45 on 8/14/2008. The NMOC samples were taken from roughly 10:00 on 8/13/2008 to roughly 13:00 on 8/14/2008. The particulate samplers were in operation from 11:00 on 8/13/2008 to 11:00 on 8/14/2008. The background site was located approximately 0.2 miles to the southeast of the well pad, and approximately 200 feet lower in elevation. Table 15 lists the sampler location coordinates, and the types of samplers at each location.

Figure 25. Site H Sampling Locations and Surrounding Wells

Table 15. Site H Instrument Locations

Site	Sampling Location	Latitude	Longitude	Instrument Types
H	North (N)	39.487083°	-108.042650°	NMOC, $PM_{2.5}$
	South (S)	39.486317°	-108.042633°	NMOC, $PM_{2.5}$
	East (E)	39.486817°	-108.041933°	NMOC(x2), VOC, MET, $PM_{2.5}$(x2)
	West (W)	39.486450°	-108.043300°	NMOC, $PM_{2.5}$
	Background (C)	39.484783°	-108.040183°	NMOC, $PM_{2.5}$

Figure 26 shows the particulate concentrations recorded at each of the sampling locations around Site H. All samples were taken over a 24-hour period. At this site, the concentrations fell in the 7 to 12 microgram per cubic meter range as at the previous drilling sites. The primary eastern site showed the highest concentration with 9.0 μg/m^3, with the secondary site showing the third highest concentration. When the primary and secondary sampler values were averaged for the east site, however, their value of 8.4 μg/m^3 give the eastern site the highest value overall. The northern site was second at 7.9 μg/m^3, and the southern site was a close third at 7.7 μg/m^3. Overall, the average concentration seen at the samplers located directly around the well pad was 7.9 μg/m^3, which is only slightly higher than the concentration seen at the background site (7.3 μg/m^3). The lowest particulate value was recorded at the western site, though it was only slightly lower than the values of the remaining samplers at 7.1 μg/m^3.

The primary wind direction recorded at this site was from the south, ranging from SSE to SSW. There was also a small percentage of wind that came from a northerly direction. A graph of the wind and VOC concentration detection frequencies can be seen in Figure 27. It clearly shows that the majority of the time a measurable wind speed was recorded, it was coming from a south-southwesterly direction. Also seen in this figure are the frequencies with which wind speeds were detected with and without a simultaneous VOC concentration detection. Of the only 20 or so times that there was no VOC concentration detected at this site, 8 of those times, or 40%, the wind was from the SSW. Just over 25% of the time when winds were from the SSW, VOC concentrations were detected.

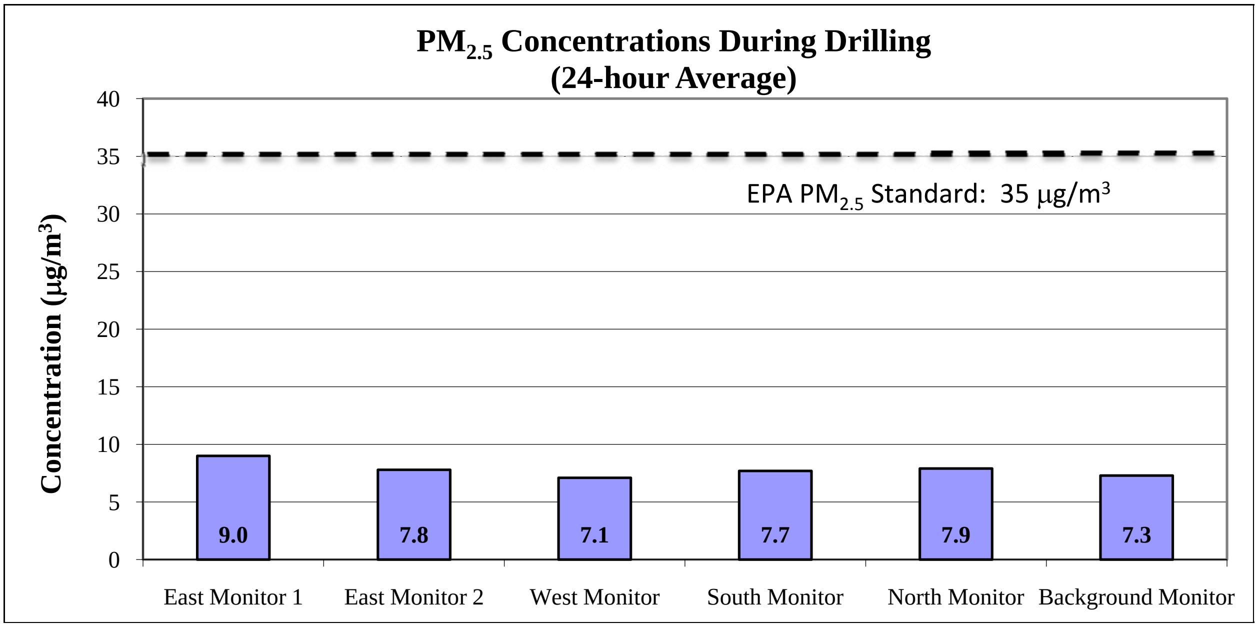


Figure 26. $PM_{2.5}$ Concentrations for Site H

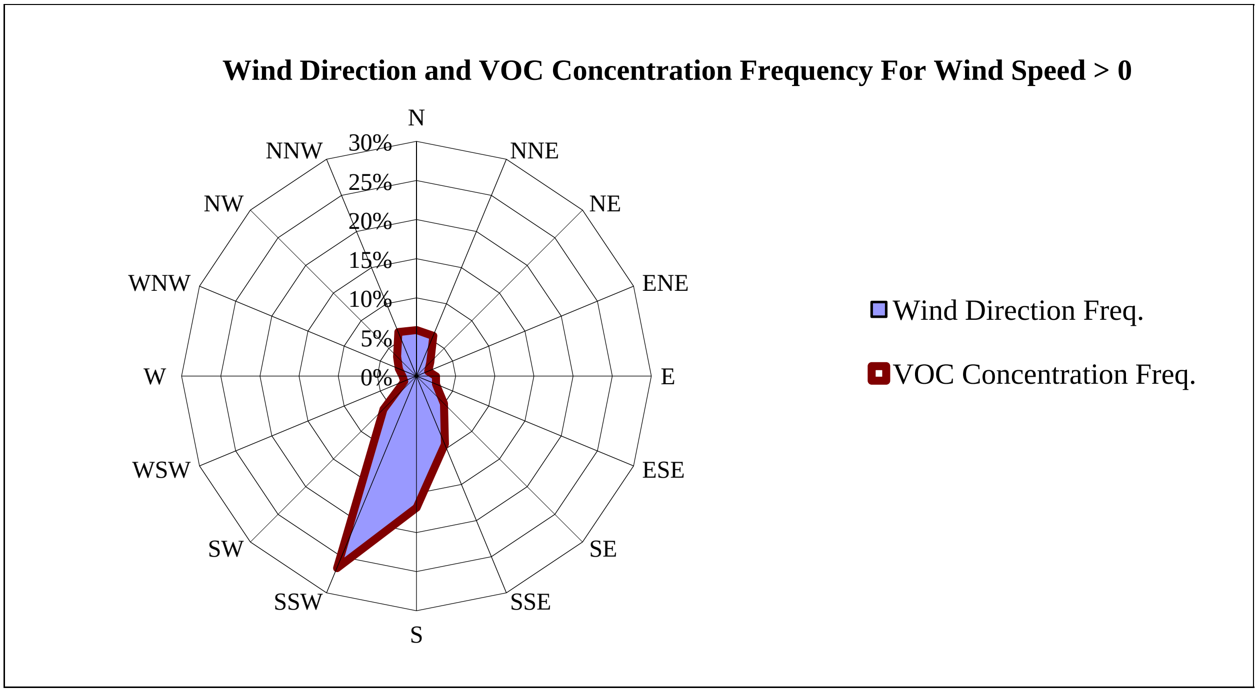


Figure 27. Wind Direction and Concentration Frequency at Site H

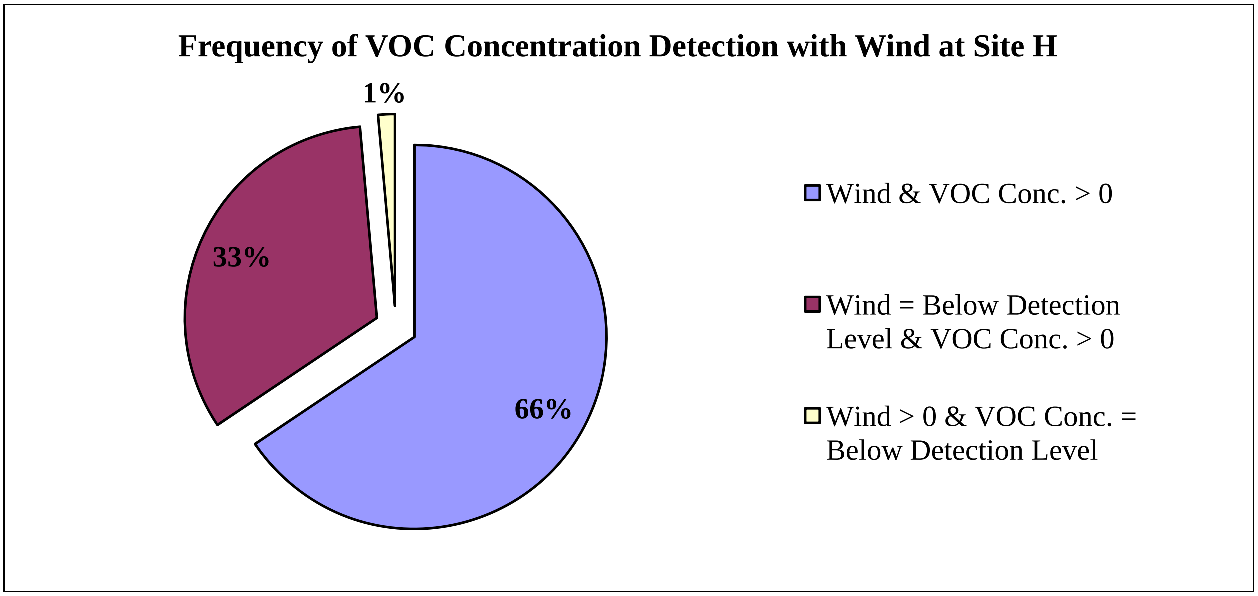


Figure 28. Frequency of VOC Concentration and Wind Speed Detection for Site H

This statement is better illustrated with a quick look at Figure 28. It clearly shows that there were very few times where the VOC concentration was zero. Approximately 1% of the time at this site there was not a VOC concentration detected, either with or without a measurable wind speed. The remaining 99 % of the time there were concentrations detected—66% of the time they were with a measurable wind speed and 33% of the time they were not. At no time was there no measured wind speed or VOC concentrations detected.

At the beginning of the VOC sampling session, there was a large amount of wind from the southern direction. At the same time, the VOC concentrations were approximately 100 ppbv or less. Once the wind died down some, the concentrations rose considerably, spiking to values of over 1,100 ppbv at times. The biggest spike occurred between 20:00 and 21:00, at which time the production tanks were being cleaned, according to the site activity log provided by the drilling company. The plotted time series data for wind speeds and VOC concentrations can be seen in Figure 29.

At 05:00 on 8/14/2008 drilling began. At this time, a corresponding increase in VOC concentrations is seen. There appears to be an increasing "background" concentration of VOCs from roughly 18:45 to approximately 07:00 the next day. After 07:00, these background concentrations begin to decrease until the sampler is stopped. The average wind speed recorded throughout the duration of the sampling period was 3.6 mph, with spikes to around 23 mph at times. The total average VOC concentration was 166 ppbv. When the higher wind speeds are seen at the beginning of the sampling session, there is a lower "background" VOC concentration. The average wind speed during that time, from approximately 13:00 to approximately 20:00, was 8.3 mph, with a VOC average of 42 ppbv. From that point on, however, the average wind speed was 1.6 mph and the average VOC concentration was 220 ppbv. The average VOC concentration over the entire sampling period, as well as the maximum value observed are listed in Table 16, and are 166 and 1116 ppbv, respectively.

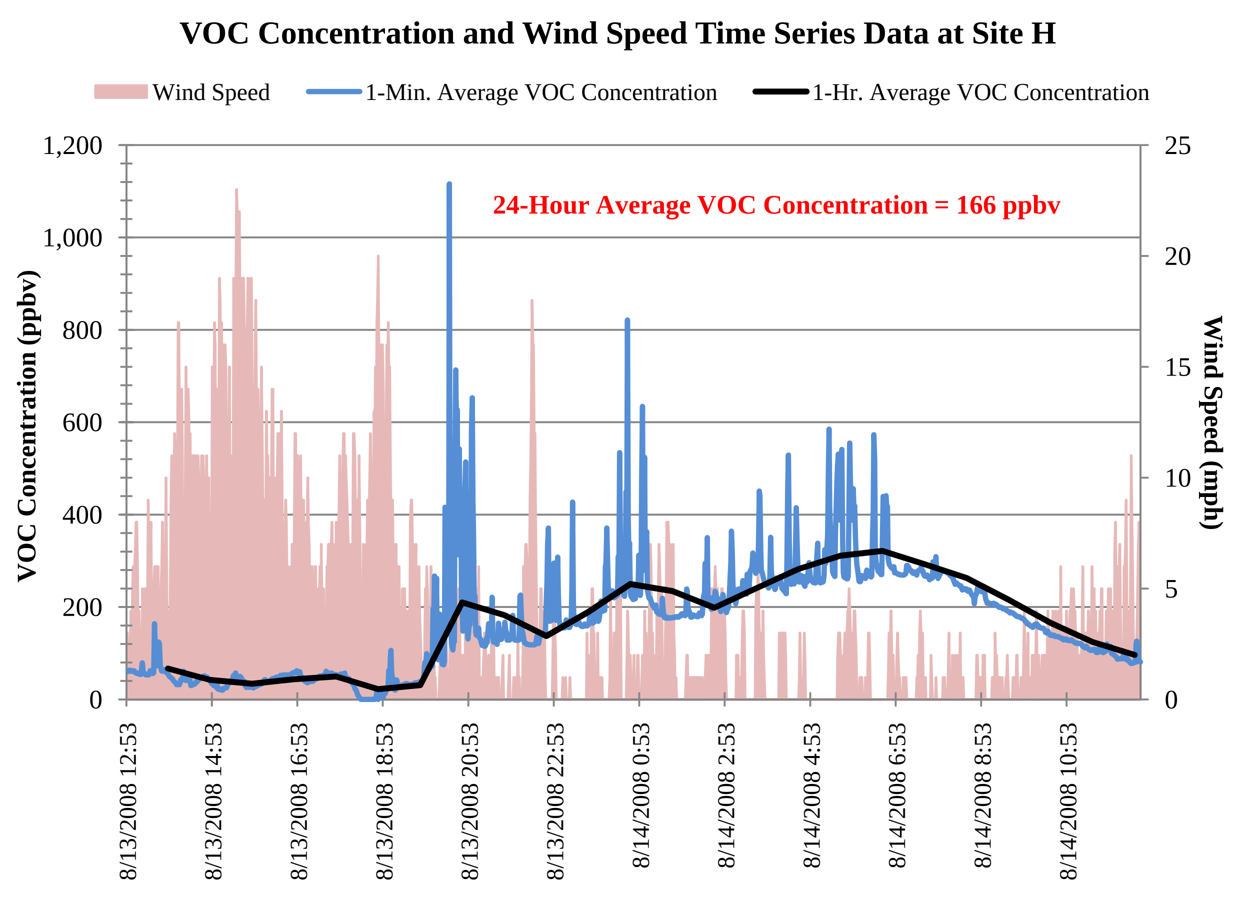


Figure 29. Time Series Data for VOC Concentrations and Wind Speeds at Site H

Table 16. Maximum and Average VOC Concentrations

Maximum VOC Concentration (taken from 1 minute avgs.)	Average VOC Concentration (averaged over 24 hours)
1,116 ppbv	166 ppbv

Figure 30 shows the NMOC concentrations obtained as a result of this study. The samplers were run from approximately 10:00 on 8/14/2008 to approximately 13:00 on 8/15/2008, for a total sampling time of 27 hours. The north site recorded the highest TNMOC and unknown values at 495 and 149 ppbC, respectively. It had only the third highest SNMOC concentration, however. The average concentrations over the well pad area were 355, 84 and 439 ppbC for SNMOCs, unknowns and TNMOCs. The SNMOC and TNMOC concentrations were lower than those of the background site at 387 and 443 ppbC, respectively. Both the well pad averages and the background monitor values are listed in Table 17, along with their relative percent differences. The background site's unknown concentration, however, was the lowest of all the sites at 55 ppbC, or 12% of the TNMOC total for the site. The pad samplers averaged an unknown concentration of approximately 19%, with the highest value belonging to the north site at 30%. Averaged over all of the samplers, the SNMOC concentration was quite similar to that obtained during the 2006 Front Range study—361 versus 371 ppbC, with the Front Range having the higher concentration. As was seen with the previous drilling sites, however, the unknown percentages for this site were much lower than those for the Front Range study (18% versus 58%).

The TNMOC concentrations were quite dissimilar as well. The value averaged over all samplers for this site was 440 ppbC, and that observed during the Front Range study was 913 ppbC. For Site H, the eastern sites showed the highest SNMOC concentrations, but the 2nd and 3rd highest TNMOC concentrations. This is due to the large proportion of unknowns that were recorded at the northern site, giving it the highest TNMOC concentration. The duplicate samplers at the eastern site did record very similar concentrations for SNMOCs, unknowns and TNMOCs.

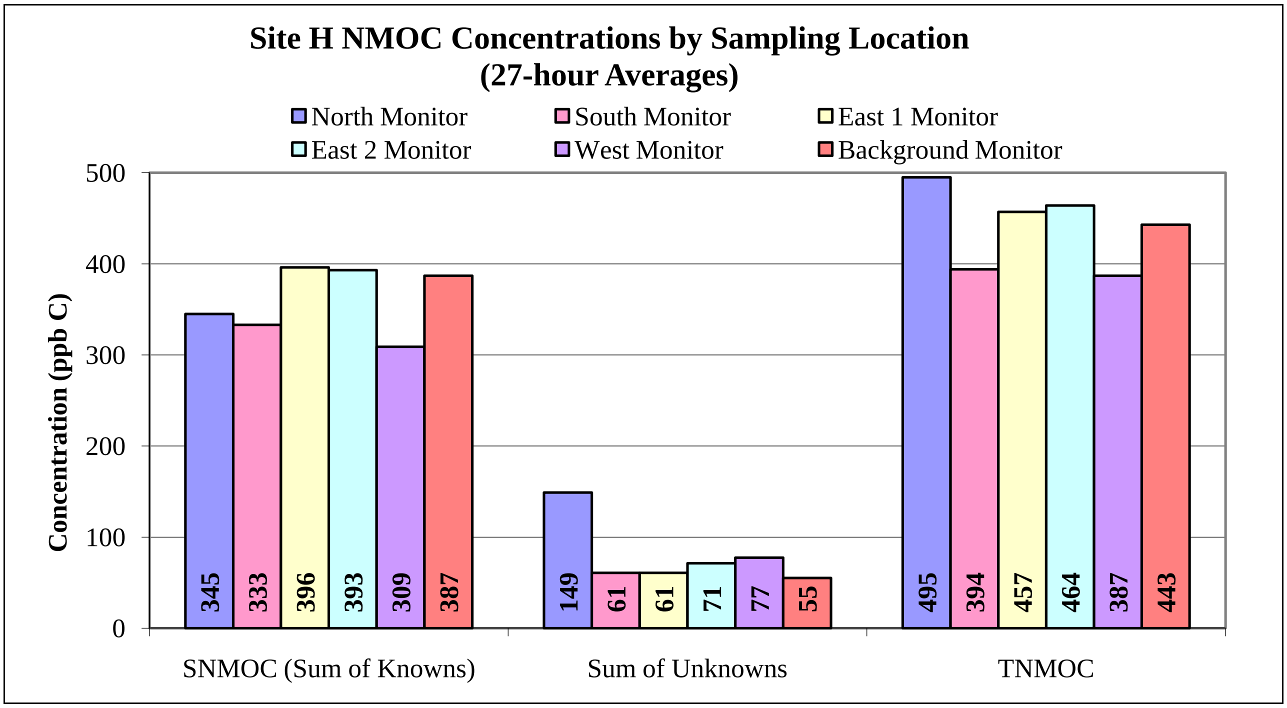


Figure 30. NMOC Concentrations by Sampling Location at Site H

Table 17. Well Pad Avg. and Background Monitor NMOC Sample Concentrations and RPD

	Well Pad Avg. Concentration (27-hour avg.) ppbC	**Background Monitor Concentration (27 hour avg.) ppbC**	**RPD %**
SNMOC	355	387	9
Sum of Unknowns	84	55	42
TNMOC	439	443	1

Figure 31 is a graph showing the concentrations of the two speciated compounds recording the highest values at the sampling locations—ethane and propane. The reader should note here that the ethane concentration values shown are estimates, as the actual values recorded by the analytical process were above the upper detection limit (UDL) of the instrument (50 ppbv). In any further mention of ethane concentrations for this particular site it should be kept in mind that the values mentioned are estimates.

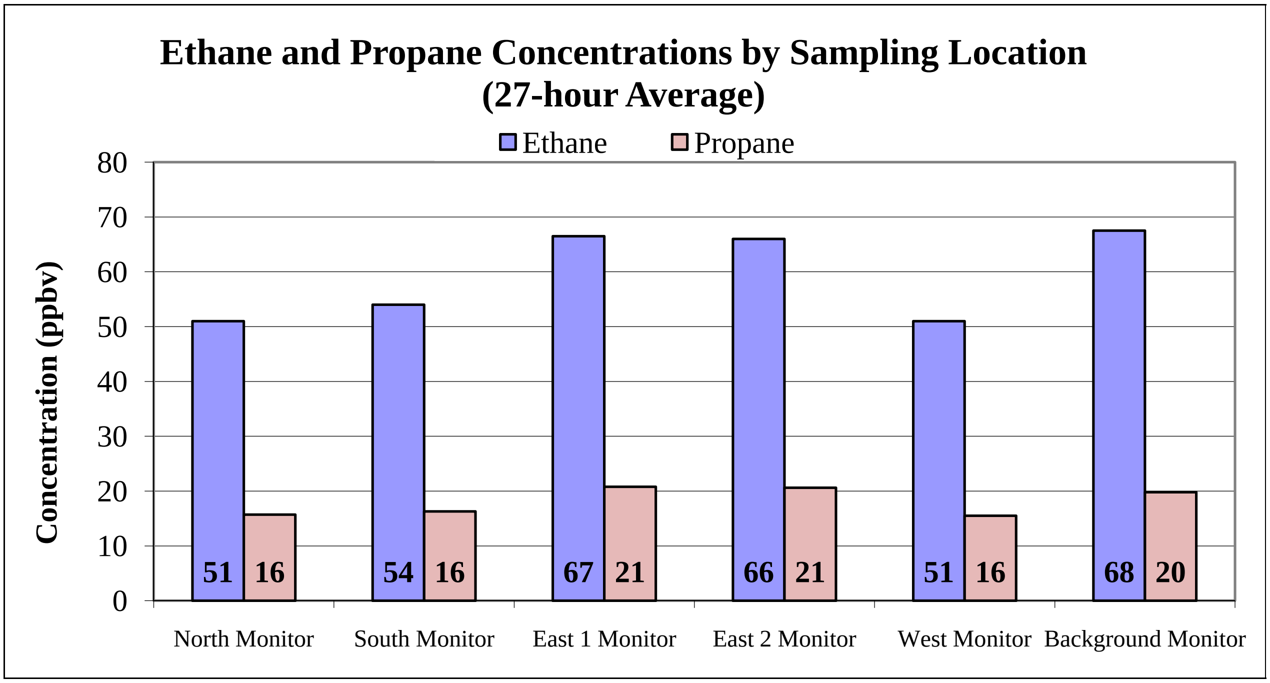


Figure 31. Ethane and Propane Concentrations by Sampling Location at Site H

The northern site saw an ethane concentration of 51 ppbv. This site also had two compounds that co-eluted with unknown peaks. These were 2-methyl-1-butene and isobutene/1-butene. Of the remaining 75 compounds, 20 were non-detectable/non-reportable and 55 were detectable. Of the 55 detected, propane was the highest non-estimated value at near 16 ppbv. All other concentrations were less than 5 ppbv. As was previously mentioned, this site saw nearly double the concentration of unknowns than the other sites did—149 ppbC versus 77 ppbC or less at the other sites.

The southern site saw ethane at an estimate of 54 ppbv. Of the 77 compounds remaining, 27 were non-detectable/non-reportable and 50 were detected. As with the northern site, propane was the largest non-estimated concentration at approximately 16 ppbv. Again, all other concentrations were less than 5 ppbv. There was a 15% concentration of unknowns relative to the TNMOC concentration.

The eastern sites both saw ethane concentration estimates over 65 ppbv. Of the 77 remaining compounds at each site, 26 were non-detectable/non-reportable for the primary site and 23 for the secondary site. Of the 51 remaining at the primary site and the 54 remaining at the secondary site, propane had the highest concentration at both sites with a value of 21 ppbv. The relative percent differences between the SNMOC, unknown and TNMOC values obtained for duplicate samples at this site were very small, at 1, 15 and 2%, respectively. The RPD for each speciated compound detected by the collocated monitors, and their concentration results are listed in Table 18. The average RPD between the samplers was 11%, averaged over all the samples in Table 18.

Table 18. Duplicate NMOC Sample Concentrations and RPD

ANALYTE	RESULT 1 (ppbC)	RESULT 2 (ppbC)	RPD (%)
1,2,3-Trimethylbenzene	0.433	0.468	8
1,2,4-Trimethylbenzene	1.94	1.84	5
1,3,5-Trimethylbenzene	1.05	0.968	8
1,3-Butadiene	0.179	0.177	1
1-Dodecene	0.229	0.385	51
1-Heptene	1.24	1.22	2

ANALYTE	RESULT 1 (ppbC)	RESULT 2 (ppbC)	RPD (%)
1-Hexene	0.199	0.188	6
1-Nonene	0.225	0.289	25
1-Pentene	0.217	0.234	8
1-Undecene	0.338	0.341	1
2,2,3-Trimethylpentane	0.401	0.341	16
2,2-Dimethylbutane	0.954	0.978	2
2,3-Dimethylbutane	1.58	1.6	1
2,3-Dimethylpentane	0.811	0.8	1
2,4-Dimethylpentane	0.597	0.661	10
2-Methyl-1-butene	2.1	1.69	22
2-Methylheptane	1.58	1.6	1
2-Methylhexane	2.37	2.26	5
2-Methylpentane	6.63	7.19	8
3-Methylheptane	1.19	1.25	5
3-Methylhexane	2.31	2.29	1
3-Methylpentane	3.67	3.73	2
Acetylene	3.07	3.1	1
a-Pinene	0.994	0.719	32
Benzene	2.58	2.59	0
cis-2-Butene	0.147	0.176	18
Cyclohexane	4.66	4.73	1
Cyclopentane	0.807	0.82	2
Cyclopentene	0.16	0.331	70
Ethane	134	132	2
Ethylbenzene	0.721	0.669	7
Ethylene	3.08	3.25	5
Isobutane	21.4	21.2	1
Isobutene/1-Butene	14.9	13.6	9
Isopentane	23.6	22.6	4
Isoprene	0.417	0.494	17
Isopropylbenzene	0.221	0.285	25
m-Diethylbenzene	0.547	0.331	49
Methylcyclohexane	10.2	10.3	1
Methylcyclopentane	4	4.16	4
m-Ethyltoluene	0.874	0.851	3
m-Xylene/p-Xylene	4.64	4.5	3
n-Butane	20.9	20.5	2
n-Decane	3.96	3.88	2
n-Dodecane	1.81	2.4	28
n-Heptane	4.32	4.33	0
n-Hexane	7.08	7.02	1
n-Nonane	3.25	3.21	1
n-Octane	4.28	4.92	14
n-Pentane	11.5	11.4	1
n-Propylbenzene	0.413	0.392	5
n-Tridecane	0.461	0.905	65

ANALYTE	RESULT 1 (ppbC)	RESULT 2 (ppbC)	RPD (%)
n-Undecane	3.68	3.89	6
o-Ethyltoluene	0.859	0.752	13
o-Xylene	1.07	1.08	1
p-Diethylbenzene	0.265	0.331	22
p-Ethyltoluene	0.642	0.653	2
Propane	62.6	61.8	1
Propylene	1.23	1.25	2
SNMOC (Sum of Knowns)	396	393	1
Sum of Unknowns	58.2	70	18
TNMOC	454	463	2
Toluene	5.89	5.95	1
trans-2-Butene	0.156	0.255	48

The western site exhibited the same familiar trend of estimated ethane concentrations at a value of just over 50 ppbv. In addition, at this site there was a co-eluting unknown compound with isobutene/1-butene. Of the 75 remaining compounds, 23 were non-detectable/non-reportable and 53 were detected. Of those 53, propane was again the highest with a value of 16 ppbv, and all others were less than 5 ppbv.

The background site recorded an SNMOC concentration that was second, behind the values obtained at the eastern sites. The lowest percentage of unknowns was at this site, with a value of 55 ppbv, or 12% of the TNMOC concentration. This site also showed the third highest TNMOC value behind the eastern and northern samplers. The estimated ethane concentration was over 65 ppbv. Of the remaining 77 compounds, 27 were non-detectable/non-reportable and 50 were detected. As with all the other samplers at Site H, propane was the highest non-estimated concentration at near 20 ppbv. All other NMOC concentrations were less than 6 ppbv.

In summary, the average of the particulate concentrations recorded around the well pad (7.9 μg/m^3) was much lower than the EPA's recommended 24 hour maximum exposure value (35 μg/m^3), and appears to be fairly uniform for this site when compared to the value obtained by the background monitor (7.3 μg/m^3) and the relative percent difference of 8% between the two values. The duplicate samples taken show some agreement with a relative percent difference of 14% between the samplers. The 24-hour average VOC concentration of 166 ppbv that was observed appears to be highly dependent on the local meteorological conditions around the site, meaning that if the wind was not blowing in a direction that pushed the VOC plume toward the monitor concentrations were not recorded. The one-minute maximum VOC concentration observed was 1,116 ppbv. The primary wind direction at this site was from the south, with an average speed of 3.6 mph. The NMOC concentrations also seem to be rather uniform for this site, as the average of the concentrations around the well pad is similar to the values recorded by the background monitor. The well pad averages for SNMOCs, unknowns and TNMOCs were 355, 84, and 439 ppbC, respectively, while the background monitor concentrations were 387, 55 and 443, respectively. This gives an average relative percent difference of 17% between the background and well pad monitors. The duplicate NMOC samples showed good agreement with an average relative percent difference of 6% between the samplers.

5.1.5 DRILLING SUMMARY

The well pad average particulate concentrations seen at all the drilling sites were fairly uniform, ranging from a low of 7.8 μg/m^3 at Site D, to a high of 9.3 μg/m^3 at Site B. The concentrations at the background sites ranged from 5.0 μg/m^3 at Site F to 8.2 μg/m^3 at Site B. The highest particulate concentration recorded at any of the sites was 11.4 μg/m^3 at the north sampler of Site D. Figure 32 shows the average concentrations obtained at each well pad, in addition to the concentrations obtained at each of the background sampling locations associated with each site.

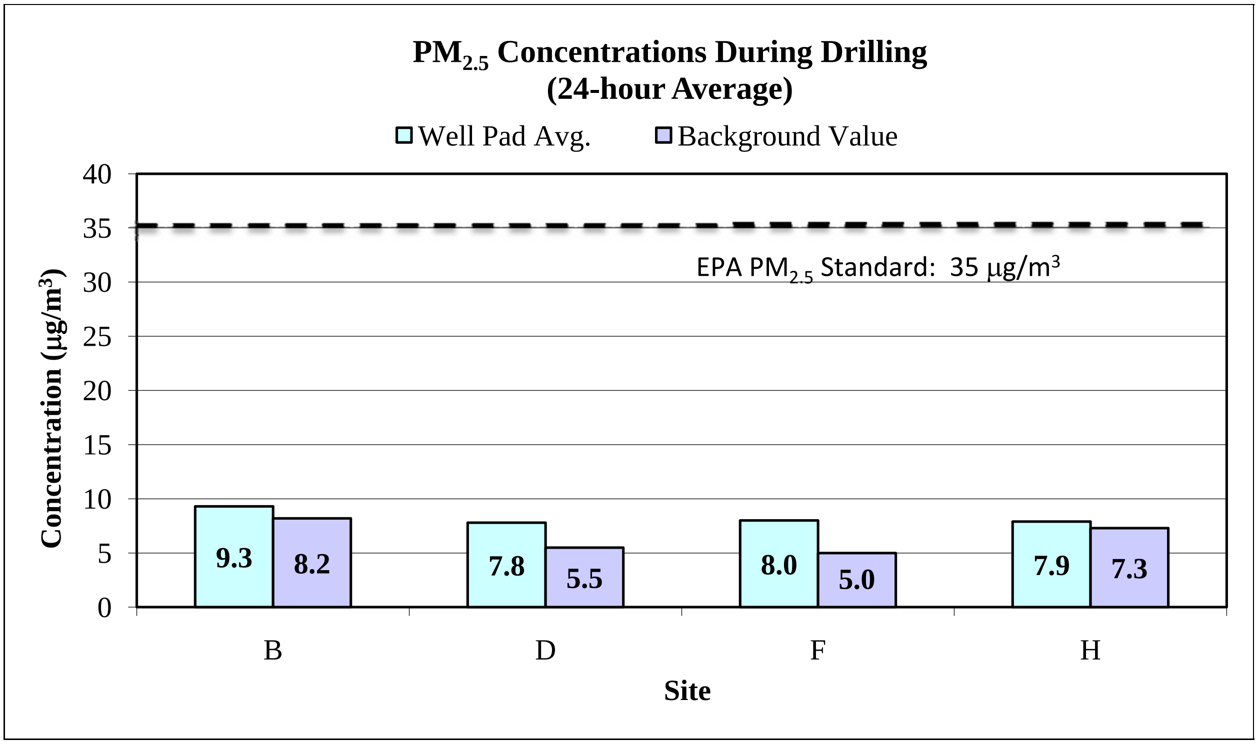


Figure 32. Average Drilling Concentrations – PM$_{2.5}$

Table 19. Well Pad Avg. and Background Monitor PM$_{2.5}$ Concentrations and RPD

Site	Well Pad Avg. Conc. (µg/m^3) (24-hr. avg.)	Background Monitor Conc. (µg/m^3) (24-hr. avg.)	RPD (%)
B	9.3	8.2	13
D	1.8	5.5	35
F	8.0	5.0	46
H	7.9	7.3	8

Table 20. Collocated Particulate Sampler Concentrations and RPD

Site	Result 1 (µg/m^3)	Result 2 (µg/m^3)	RPD (%)
B	10.4	6.8	42
D	8.0	7.6	5
F	8.0	7.8	3
H	9.0	7.8	14

Table 19 lists the average PM$_{2.5}$ concentrations around the well pads, and those recorded at the background monitor. Table 20 lists the results and relative percent differences of the duplicate PM$_{2.5}$ samples taken at each well pad. The average RPD between the well pad averages and background monitor values was 26%, while that of all the collocated particulate monitors was 16%. Site H had the lowest RPD of between the well pad and the background monitors at 8%, while Site F had the lowest of the collocated monitors at 2.5%. Site D also had a low RPD with a value of just fewer than 5%.

Three of the sites, Sites B, F and H, all had the primary winds coming from a southerly direction: south-southwesterly at Sites H and F, and south-southeasterly at Site D. The secondary wind directions at Sites F and H were from a northerly direction. Site D's secondary wind direction was from the west. Site B had a varied wind pattern throughout the duration of the sampling. There is a large amount of wind from the west to northwesterly direction, but there is also a significant amount from the east-northeasterly direction as well. This may indicate a more thoroughly mixed atmosphere around the well pad.

The VOC samplers were not all run for the same amount of time. The sampler at Site F was run for only 14 hours, while the sampler at Site H was run for 24 hours, and the samplers at Sites B and D were run for 27 hours. The highest 1-minute average VOC concentrations were seen at Site B, with values spiking to near 2,000 ppbv. The average over the entire sampling period was approximately 25 ppbv for that site. The average wind speed during this time was 1.8 mph. Site H had the second highest 1-minute average VOC concentration recorded with a value spiking to over 1,100 ppbv. The average over the sampling period there was 166 ppbv, with an average wind speed of 3.6 mph. Site F had the third highest VOC concentration spike with a value over 300 ppbv, even though the sampler was in operation for only 14 hours. The average concentration over the sampling period at this site was 6 ppbv, with a wind speed of 2.4 mph. During the one burst of VOC activity, however, the average VOC concentration was 26 ppbv with an average wind speed of 4.5 mph. Site D had VOC concentration spikes to near 170 ppbv. The average recorded over the sampling period was 34 ppbv, which is the second largest of the average concentrations (Site H was number 1). The average wind speed during that time was 5.4 mph. During the actual VOC "event," however, the average concentration was 76 ppbv and the average wind speed was 3.3 mph. Figure 33 shows the average VOC concentrations obtained at all the drilling sites.

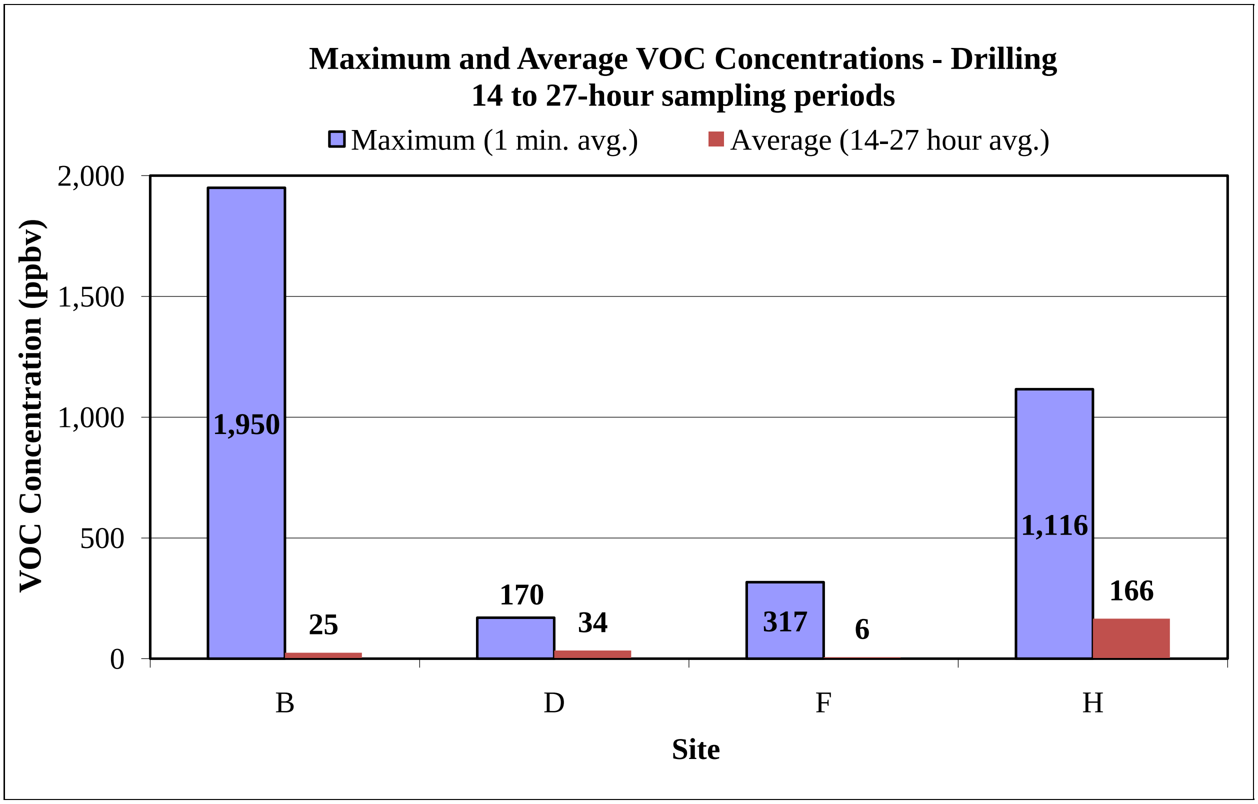


Figure 33. Average Drilling Concentrations - VOCs

The NMOC samplers were not all run for exactly the same sampling period, but were within 1 – 2 hours total time of each other, ranging from 25 to 27 hours. As such, the concentrations obtained are assumed to be similar enough for comparison purposes in this report. Site B monitors were run for 27 hours, while Sites D, F and G were run for 26, 25, and 27 hour periods, respectively. Site D had the highest average concentration of TNMOCs with a value of 664 ppbC. It also had the highest recorded value for SNMOC concentrations at 529 ppbC, and for unknowns at 135 ppbC. The unknown concentrations account for an average of 17% of the total NMOC concentration. Site H had the second highest TNMOC average with a value of 440 ppbC. It was also second for SNMOC values at an average concentration of 361 ppbC. It was in third place for average unknown concentrations, however, with a value of 79 ppbC, which equates to an average of 18% of the total NMOC concentration. Site B averaged the third highest TNMOC concentration with its value of 358 ppbC. It was in last place for SNMOC averages, though, with a value of 248 ppbC. This site ranked second place in the unknown concentrations, however, with an average value of 111 ppbC, or 30% of the total concentration, which is the highest percentage of unknowns seen at any of the drilling sites. Site F had the lowest average TNMOC concentration with a value of 322 ppbC, and the second lowest SNMOC concentration with an average value of 262 ppbC. The average unknown concentration was the lowest value at 60 ppbC, but the second highest percentage of unknowns at any of the drilling sites. This information can be seen in Figure 34 and Figure 35.

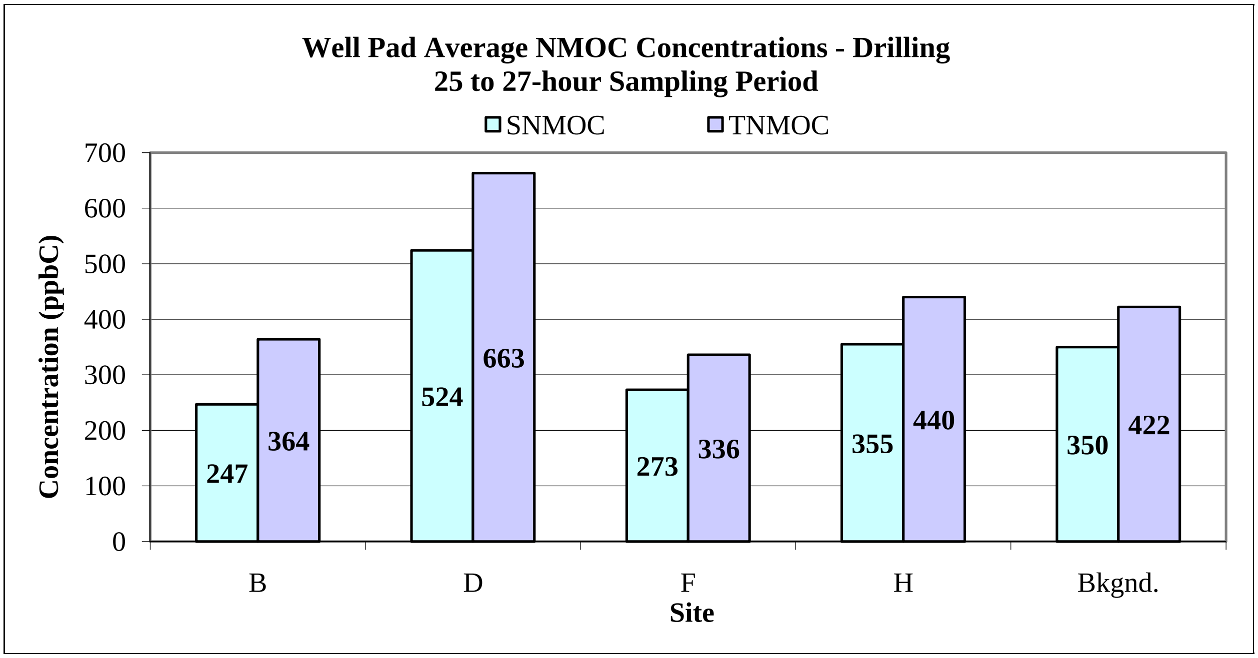


Figure 34. Average Well Pad Drilling Concentrations – TNMOC and SNMOC

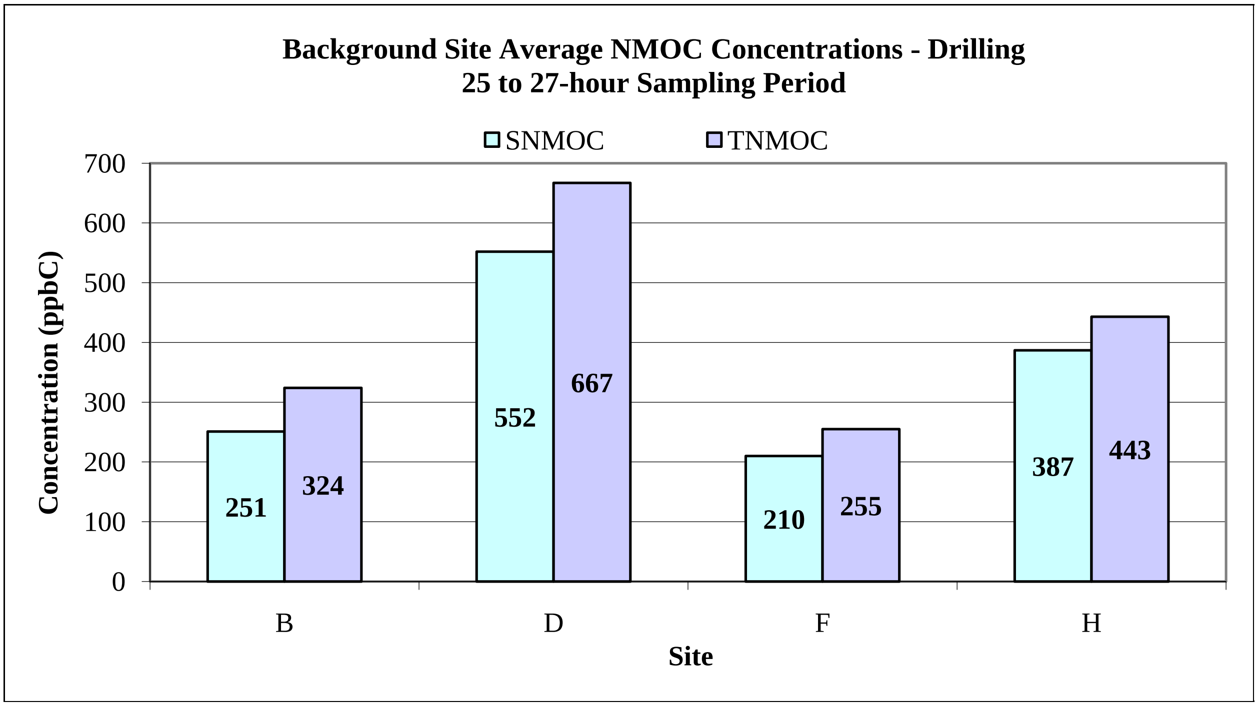


Figure 35. Average Background Site Drilling Concentrations – TNMOC and SNMOC

A comparison of the NMOC compounds reveals that there were only 8 compounds that were commonly not detected at each of the drilling sites. There were 9 that were detected at two or more sites, and there were 6 that were not detected at only one of the sites. The highlighted compounds in Table 21 are those that were non-detectable/non-reportable at all drilling sites. At Site B there were 18 compounds that weren't detected at all the samplers, and 16 others that were not detected at some of the samplers. At Site D there were 11 compounds not detected at all the samplers and 21 others at some of the samplers. At Site F there were 17 compounds not detected at all the samplers, and 30 others that were not detected at some of the samplers. Site H had 18 compounds not detected at all samplers and 17 others not seen at some of the other monitors.

Table 21. Commonly Non-Detected Compounds at All Drilling Sites

Site B	Site D	Site F	Site H
1,3-Butadiene		1,3-Butadiene	1,3-Butadiene
1-Decene	1-Decene	1-Decene	1-Decene
			1-Dodecene
1-Hexene	1-Hexene	1-Hexene	1-Hexene
1-Nonene	1-Nonene	1-Nonene	
1-Octene		1-Octene	1-Octene
1-Tridecene	1-Tridecene	1-Tridecene	1-Tridecene
	1-Undecene		
2,2,3-Trimethylpentane			
2,2,4-Trimethylpentane		2,2,4-Trimethylpentane	2,2,4-Trimethylpentane
			2,3,4-Trimethylpentane
2-Ethyl-1-butene	2-Ethyl-1-butene	2-Ethyl-1-butene	2-Ethyl-1-butene
2-Methyl-1-pentene	2-Methyl-1-pentene	2-Methyl-1-pentene	2-Methyl-1-pentene
			2-Methyl-2-butene
3-Methyl-1-butene	3-Methyl-1-butene	3-Methyl-1-butene	3-Methyl-1-butene
cis-2-Butene		cis-2-Butene	cis-2-Butene
cis-2-Hexene			
cis-2-Pentene		cis-2-Pentene	cis-2-Pentene
Isopropylbenzene	Isopropylbenzene	Isopropylbenzene	
Propyne	Propyne	Propyne	Propyne
Styrene		Styrene	Styrene
trans-2-Hexene	trans-2-Hexene	trans-2-Hexene	trans-2-Hexene
		trans-2-Pentene	trans-2-Pentene

Table 22 lists the 45 compounds that were detected in greater than 90% of the samples taken from all the drilling sites. The compounds are placed in order from the highest ozone forming potential to the lowest ozone forming potential. The ozone reactivity is a measure of the amount of ozone that can be formed per amount of organic compound reacted. The units are typically reported as grams of O_3 formed per gram of VOC reacted.

Table 22. Compounds Detected in >90% of Samples

Analyte	MIR	Drill Avg. (ppbC)	O_3 Reactiv. MIR*avg.
Isopentane	0.50	32.6	16.4
n-Pentane	0.46	20.2	9.3
m-Xylene/p-Xylene	2.05	4.5	9.2
Toluene	1.09	8.3	9.0
Isobutane	0.41	22.2	9.0
n-Butane	0.40	22.0	8.8

Analyte	MIR	Drill Avg. (ppbC)	O_3 Reactiv. MIR*avg.
Propane	0.17	50.3	8.6
Ethane	0.10	81.2	7.9
Methylcyclohexane	0.58	9.7	5.6
Ethylene	2.65	1.9	5.1
Isoprene	3.03	1.6	4.9
2-Methylpentane	0.53	7.0	3.7
n-Hexane	0.43	7.6	3.3
Cyclohexane	0.42	7.2	3.0
Propylene	3.38	0.8	2.8
1,2,4-Trimethylbenzene	2.00	1.4	2.7
Methylcyclopentane	0.70	3.8	2.7
o-Xylene	2.07	1.2	2.5
3-Methylpentane	0.62	3.8	2.3
m-Ethyltoluene	2.61	0.9	2.3
1,3,5-Trimethylbenzene	3.12	0.7	2.1
n-Undecane	0.21	8.1	1.7
n-Heptane	0.38	4.5	1.7
1-Heptene	1.23	1.2	1.4
3-Methylhexane	0.55	2.4	1.3
n-Dodecane	0.19	6.5	1.2
o-Ethyltoluene	1.84	0.7	1.2
n-Octane	0.32	3.6	1.2
a-Pinene	1.22	0.8	1.0
n-Decane	0.24	4.1	1.0
2-Methylhexane	0.41	2.4	1.0
Cyclopentene	2.08	0.4	0.9
Ethylbenzene	0.77	1.0	0.8
Cyclopentane	0.78	0.9	0.7
p-Ethyltoluene	1.04	0.6	0.6
Benzene	0.22	2.8	0.6
n-Nonane	0.28	2.2	0.6
1-Pentene	2.26	0.2	0.5
2,3-Dimethylbutane	0.34	1.5	0.5
2-Methylheptane	0.35	1.4	0.5
Acetylene	0.34	1.3	0.4
3-Methylheptane	0.40	1.0	0.4
2,3-Dimethylpentane	0.46	0.9	0.4
2,2-Dimethylbutane	0.40	0.9	0.4
2,4-Dimethylpentane	0.49	0.6	0.3

In summary, the particulate values appear to be indicative of overall background values for the areas, and are much lower than the EPA standard. There was an average RPD of 26% between the well pad averages and the background values, and an average RPD of 16% between the collocated samplers. The meteorological parameters appear to be highly dependent on the topography surrounding each well pad, showing varied speeds and directions. The VOC samplers were not all run for the same amount of time, varying from 14 to 27 hours, which makes comparing these results difficult at best. The sampling period average VOC concentrations ranged from 6 to 166 ppbv. The NMOC samplers were also not run for the same amounts of time, ranging between 25 and 27 hours, but were similar enough that comparisons could be made rather accurately. The data shows that there are similar concentrations for most of the sites, with the exception of Site D, which recorded larger values. This would seem to indicate that the values obtained may be indicative of background concentrations in the areas as well. There were 8 compounds that were not detected at all of the sites, 9 that were not detected at 2 or more sites and 6 that were not detected at only one site. There were 45 of the 78 compounds detected in greater than 90% of the samples.

5.2 COMPLETION DATA

5.2.1 SITE A

Site A was located on the west edge of the Garfield County Airport in Rifle. There were several actively producing wells located to the south of this particular well pad. Figure 36 shows the locations of the samplers for Site A. The background sampler is approximately one half mile to the southwest of the well pad. The eastern sampling site housed the duplicate particulate and NMOC samplers, as well as the meteorological station and the continuous VOC analyzer. The VOC samples were taken from approximately 15:30 on 6/2/2008 to 04:30 on 6/3/2008. The NMOC samples were taken from approximately 16:30 on 6/2/2008 to roughly 17:30 on 6/3/2008. The $PM_{2.5}$ samplers were run from 6/2/2008 at 17:00 to the same time on 6/3/2008. Table 23 lists the sampler coordinates and the instruments that were housed at each location.

Figure 36. Site A Sampling Locations and Surrounding Wells

Table 23. Site A Instrument Locations

Site	Sampling Location	Latitude	Longitude	Instrument Types
A	North (N)	39.523567°	-107.728533°	NMOC, $PM_{2.5}$
	South (S)	39.522450°	-107.728883°	NMOC, $PM_{2.5}$
	East (E)	39.522967°	-107.727933°	NMOC (x2), VOC, MET, $PM_{2.5}$ (x2)
	West (W)	39.523083°	-107.729383°	NMOC, $PM_{2.5}$
	Control (C)	39.519417°	-107.734650°	NMOC, $PM_{2.5}$

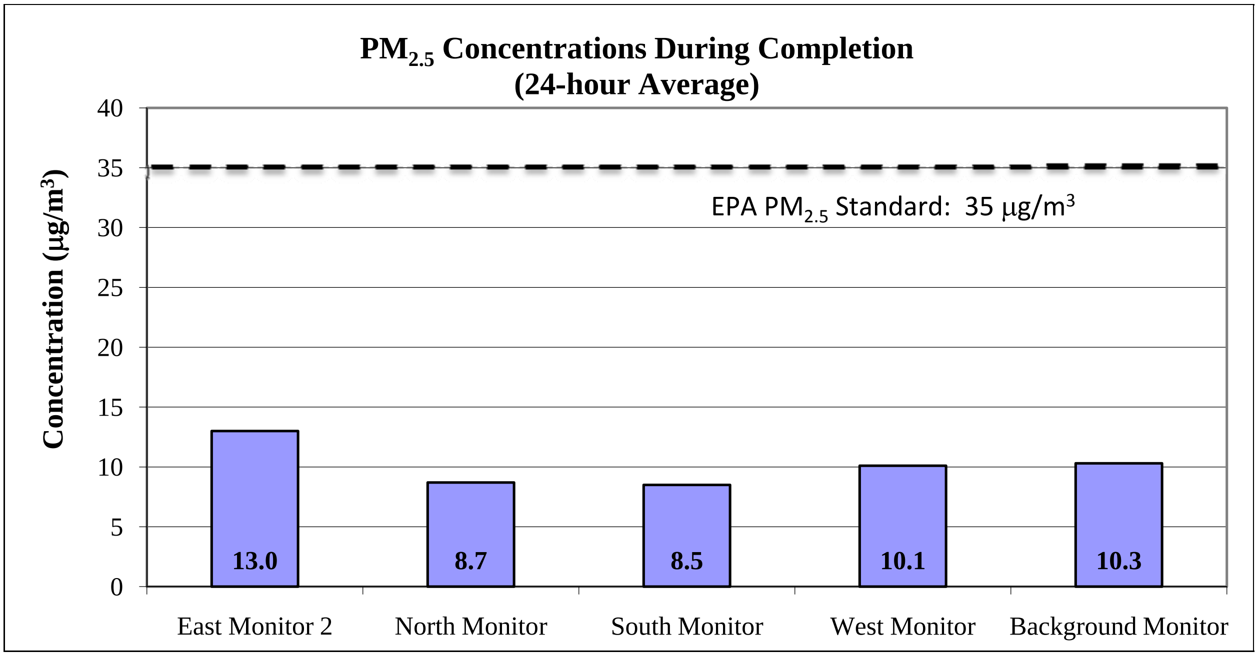


Figure 37. $PM_{2.5}$ Completion Concentrations at Site A

The particulate samplers at Site A were all run for a 24-hour time period. Figure 37 shows that the $PM_{2.5}$ data obtained lies in the 8 to 13 $\mu g/m^3$ range. There were duplicate particulate analyzers located at the eastern sampling location, and two samples were taken. Due to a lab error, however, data for only the secondary sample were obtained. This is unfortunate, as the secondary sampler obtained a particulate value of 13.0 $\mu g/m^3$; a value which cannot be confirmed as there was no duplicate data available. The remaining sites all had values from 8.5 $\mu g/m^3$ at the south site to 10.3 $\mu g/m^3$ at the background site. The average concentration over the well pad was 10.1 $\mu g/m^3$. At this location the background site did have the second highest particulate concentration, with the south site having the lowest.

The prevailing wind direction recorded at the site was in the west to southwesterly direction. There was a small amount of wind from each of the other directions, but the primary winds were from W to SW. This is illustrated in Figure 38 and Figure 39 below. They show that each time the wind blew there was an associated VOC concentration detected during the duration of time that both the samplers were in operation. This is due to the fact that there was a continual background VOC concentration detected throughout the sampling. At no time during the sampling was there a VOC concentration of zero. Figure 39 shows that 78% of the time there was a measurable wind speed detected with the VOC concentration. The remaining 22% of the time there was not.

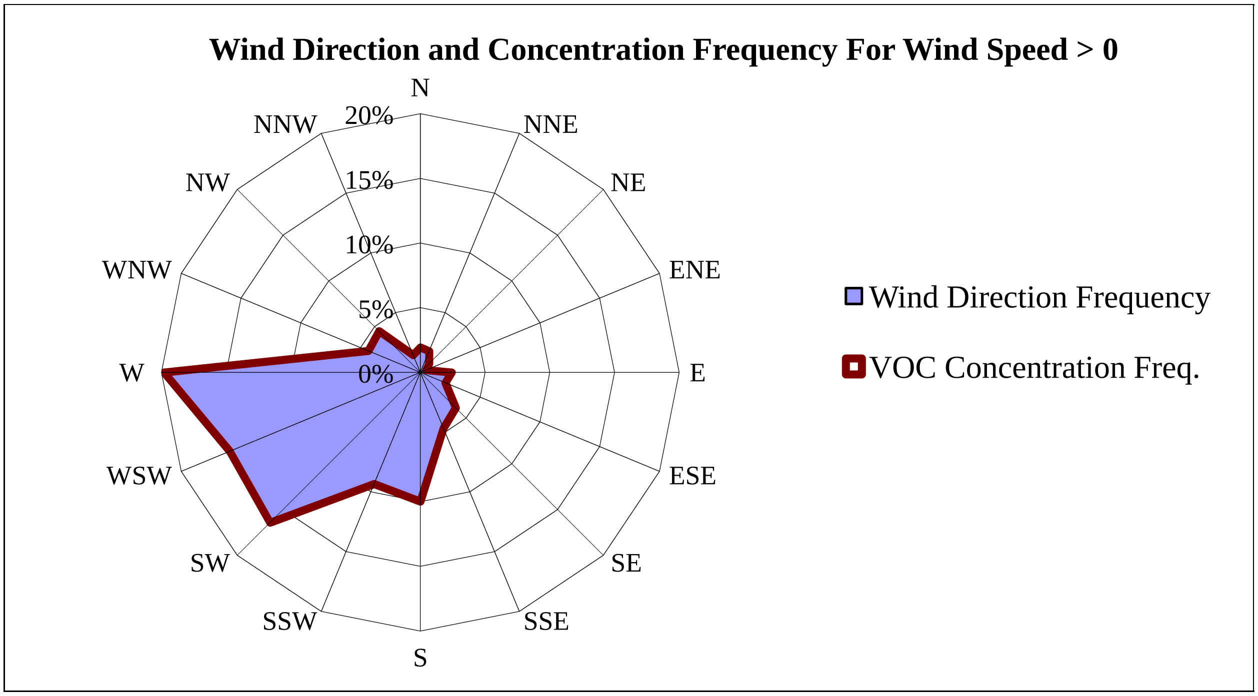


Figure 38. Wind Direction and Concentration Detection Frequency for Site A

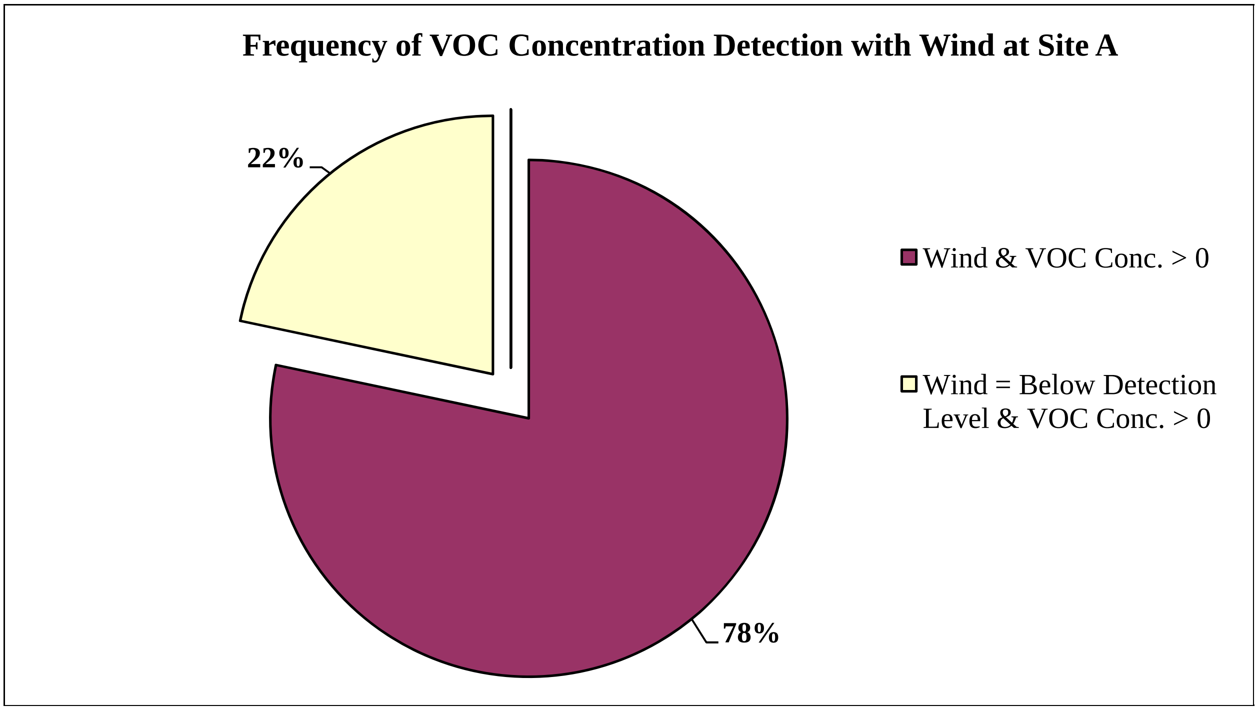


Figure 39. Frequency of Concentration Detection with Wind Speed at Site A

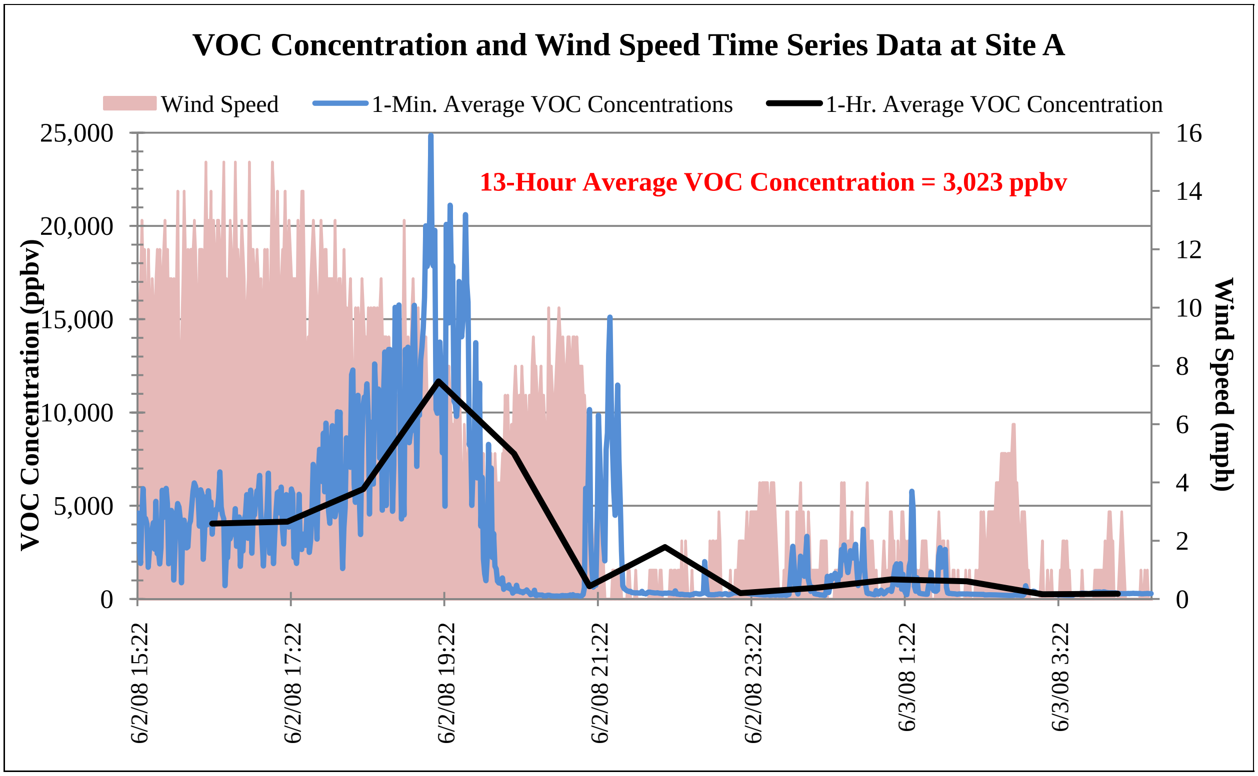


Figure 40. Time Series Data for VOC Concentrations and Wind Speeds at Site A

Table 24. Maximum and Average VOC Concentrations

Maximum VOC Concentration (taken from 1 minute avgs.)	Average VOC Concentration (averaged over 13 hours)
24,854 ppbv	3,023 ppbv

The background VOC concentration and wind speeds can be more clearly seen in Figure 40, the graph of the time series data. The VOC sampler at this location ran for only 13 hours, but observed the highest 1-minute and overall average concentrations, which are seen in Table 24. The monitor's battery died halfway through the sampling at this location. At the beginning of the sampling period, there were winds in the 10 to 15 mph range. During this same time, the 1 hour average concentrations were in the 4,000 ppbv range. As the wind speeds began to die down to the 5 – 10 mph range, the VOC concentrations began to rise. During this time, the 1 minute average VOC concentrations spiked to a value of 24,854 ppbv, while the 1-hour average concentration rose to its highest value of 11,669 ppbv.

Some of the larger spikes observed appear to have occurred around the same times as when there was a pump truck on the well pad location removing either oil or water. Also, this site had three wells flowing back to two 500 barrel (21,000 gallon) open topped tanks during the sampling period. It is worth noting here that the VOC sampler was located at the eastern monitoring area, 190 feet to the east of the open topped production tanks. This would mean that the primarily westerly wind (as was seen at this site nearly 20% of the time) would blow any evaporating compounds directly into the path of the VOC analyzer. Overall, the average VOC concentration for the entire 13-hour sampling period was 3,023 ppbv, with an average wind speed of 5 mph. The high 1-minute and 1-hour average concentrations indicate that the completion process does appear to have a much higher emissions potential than the drilling process.

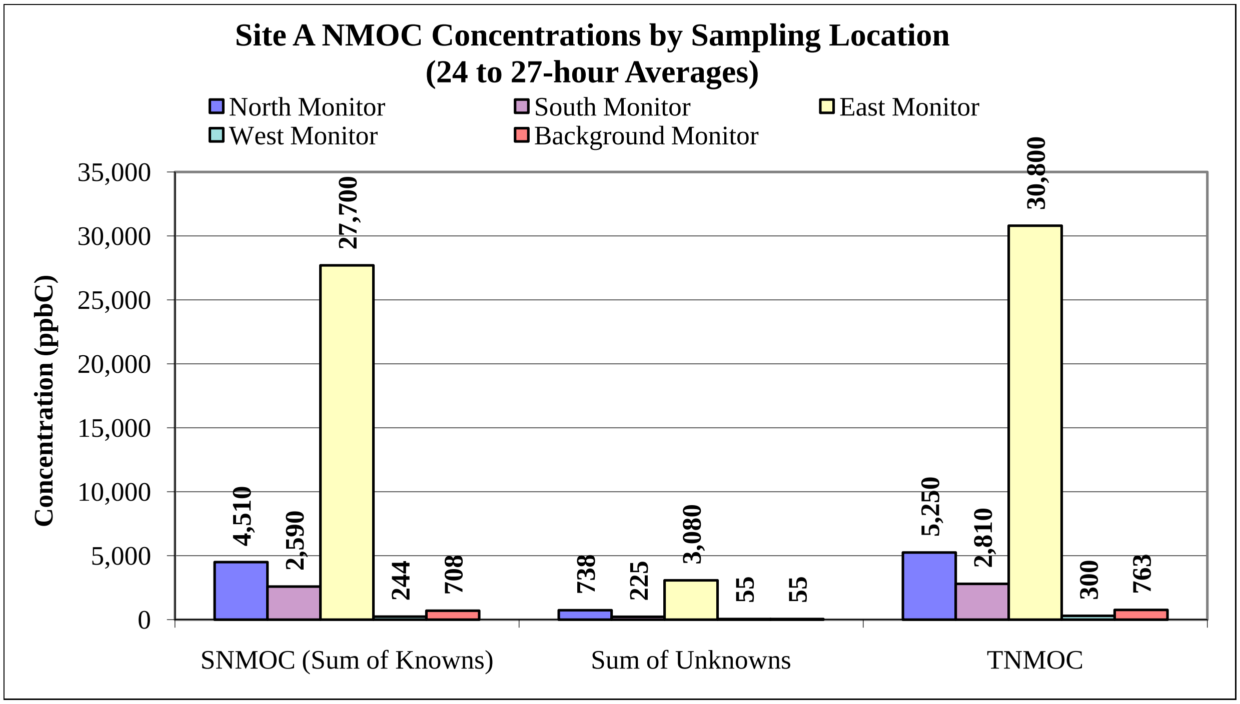


Figure 41. NMOC Concentrations by Sampling Location at Site A

Table 25. Well Pad Avg. and Background Monitor NMOC Concentrations and RPD

	Well Pad Avg. Concentration (24-25 hr. avg.) ppbC	**Background Monitor Concentration (27 hr. avg.) ppbC**	**RPD %**
SNMOC	8,761	708	170
Sum of Unknowns	1,025	55	180
TNMOC	9,790	763	171

Figure 41 is a graph of the SNMOC, unknown and TNMOC concentrations obtained during the study. The samplers for this site were not run for the same standard amount of time. The background sampler was run for 27 hours while the west sampler was run for 24 and the remaining north, south and east samplers were run for 25 hours. The eastern sampling area again showed the highest concentrations of NMOCs recorded at all sites, with values that are approximately six times higher than the next closest observation, even though the samplers were all run for 2 – 3 hours less than the background sampler was. Again, the eastern monitoring area was 190 to the east of the flowback tanks, while the southern monitors were 220 feet south of the tanks. The western monitors were 242 feet to the west of the tanks, and the northern monitors were 210 feet north of the tanks.

The duplicate sample taken at the eastern site was unusable due to a lab error. Therefore, there are no relative percent difference data available for the NMOC samples from this site. The NMOC values obtained at the eastern site appear to be in line with the VOC values observed. The TNMOC and SNMOC concentrations of 30,800 ppbC and 27,700 ppbC, respectively, appear to confirm the high VOC spike values of near 25,000 ppbv seen at the east site. The average TNMOC concentration over the well pad area was 9,790 ppbC. The average SNMOC over the pad was 8,761 ppbC, with an average unknown concentration of 1,025 ppbC, or 10% of the total NMOC concentration. These values are significantly higher than the values recorded at the background site.

The background site SNMOC, unknown and TNMOC concentrations were 708, 55 and 763 ppbC, respectively, all well under the average values established at the pad. The unknown concentration percentage was less than the average percentage with a value of 7%. It should be noted here that while the background site did have low concentrations, it did not have the lowest. The western sampling location recorded the lowest SNMOC and TNMOC concentrations, and tied for the lowest unknown concentration with the background site. This is due to the primarily westerly wind blowing the pollutants away from the western monitor.

The TNMOC, SNMOC and unknown average concentrations were all much higher at Site A than those that were recorded during the Front Range study in 2006. The Front Range concentrations for TNMOC, SNMOC and unknowns were 913, 371, and 542 ppbC. While Site A's unknown values are much higher, the overall percentage of unknowns is much small than that of the Front Range study with values of 10% and 58 %, respectively. This is likely due to the fact that the Front Range study was not conducted in the close proximity to the well production facilities that this study was and also had more urban influences.

The northern sampling site had several compound concentrations listed as estimates, as their results came in above the upper detection limit of the laboratory's analytical procedure. The highest of these concentration estimates are again the compounds of ethane and propane, with values of over 700 ppbv and 150 ppbv. This continues the trend seen at the drilling sites, with both those compounds having the highest speciated NMOC concentrations at all the drilling sites but one. The nine additional concentration estimates, however, were not seen at the drilling locations. A graph of their concentrations can be seen in Figure 42.

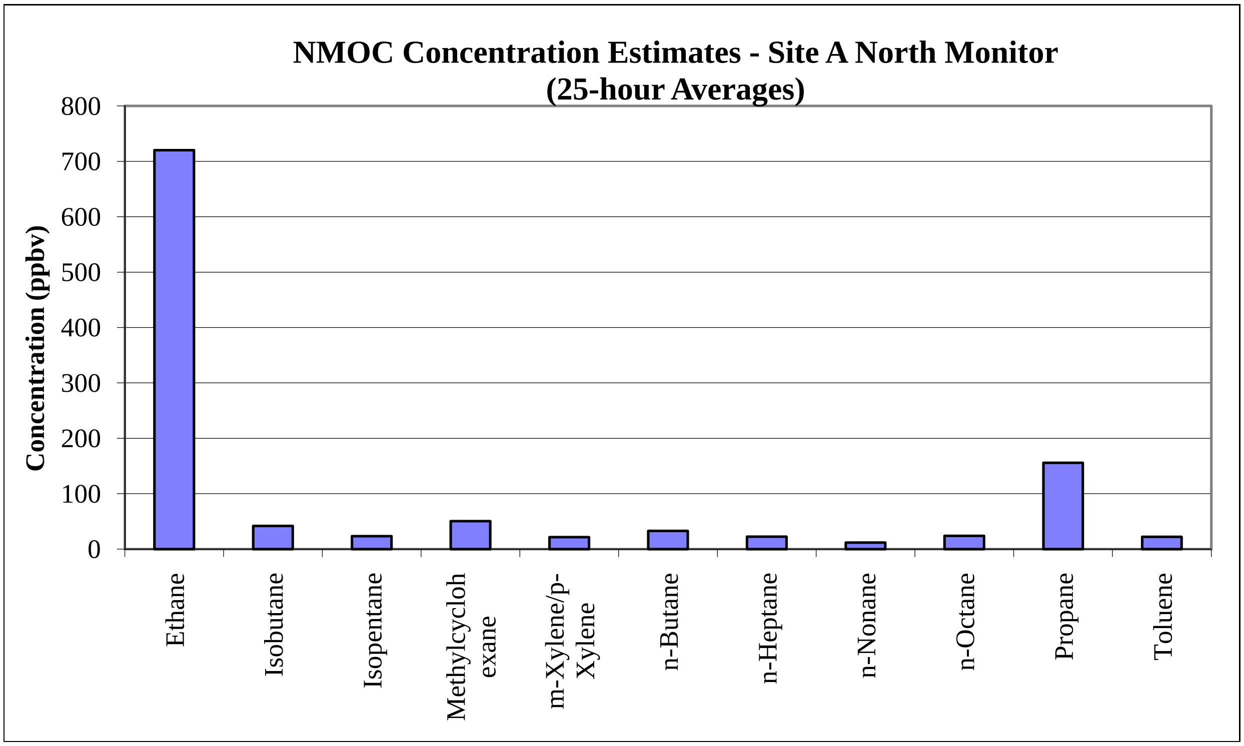


Figure 42. Speciated NMOC Concentration Estimates at Site A North Monitor

Of the 78 compounds that were analyzed for, only 13 were non-detectable/non-reportable at the northern site. This is similar to what was seen at the southern site, with only 16 non-detectable/non-reportable compounds. Ethane and propane were again the most concentrated of the speciated compounds with values of 535 ppbv and 143 ppbv, respectively. In addition to the estimated concentrations for ethane and propane, those of isobutane, isopentane and n-butane were estimated as well. A graph of their estimated concentrations can be seen in Figure 43.

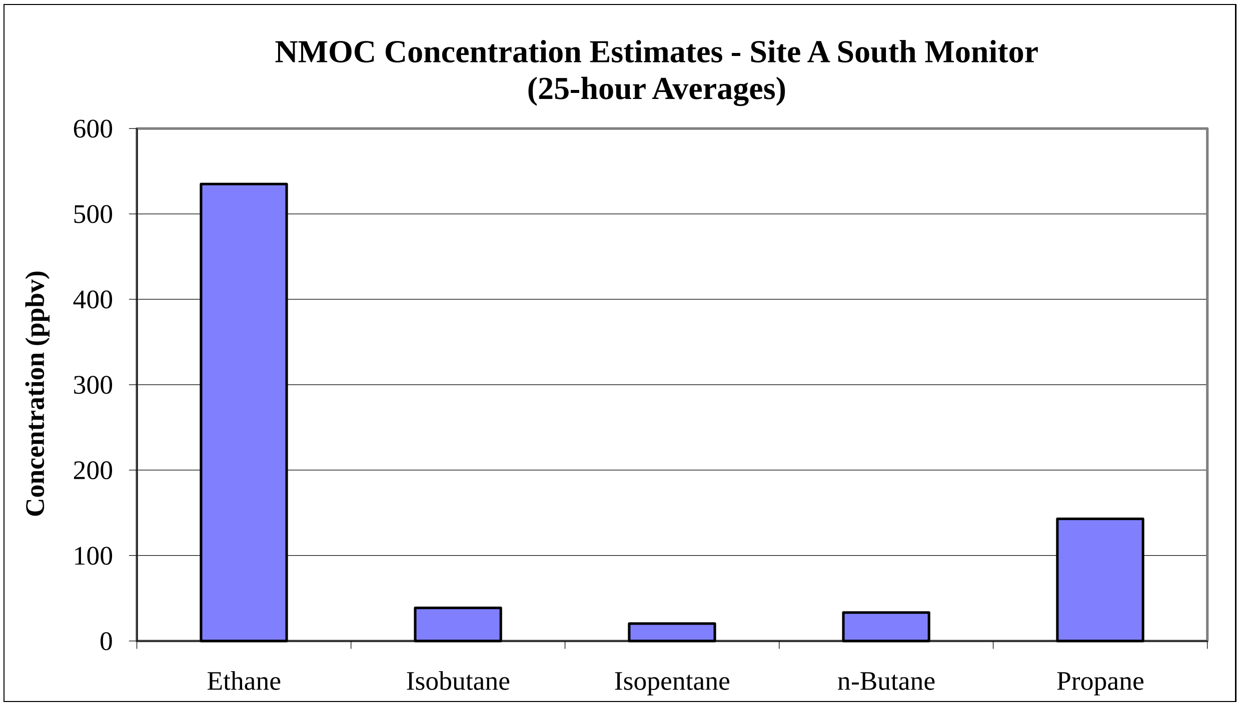


Figure 43. NMOC Concentration Estimates at Site A South Monitor

The eastern site saw a great number of estimated concentrations, due to the large volume of organic compounds that were blown in that direction. There were 29 compounds in all that had estimated concentrations. They are shown in Figure 44. This time, however, the largest estimate was not that of ethane, but of propane instead. The ethane estimate is around 2,000 ppbv, while the propane estimate is over 2,500 ppbv. In addition, both isobutane and n-butane have concentration estimates that were above the 500 ppbv mark. This large number of concentration estimates left only 13 compounds that were listed as non-detectable/non-reportable. The duplicate NMOC sampler that was located at the eastern site experienced technical difficulties during the sampling period, and no data was obtained.

The western sampling site did not have any estimated concentrations due to the primary wind direction, and the western sampler's distance from the open topped tanks. The highest concentrations seen were of ethane and propane, with values of 29 ppbv and 8 ppbv, respectively. All other recorded concentrations at this site were less than 5 ppbv. This site had the second highest number of non-detectable/non-reportable compounds at 25.

The background site did have two estimated concentrations listed, those of ethane and propane. The ethane concentration was estimated at 148 ppbv, while the propane concentration was estimated at 41 ppbv. The highest number of non-detectable/non-reportable compounds for Site A was seen at the background site. There were a total of 27 of the 78 compounds tested for that were neither detected nor reportable.

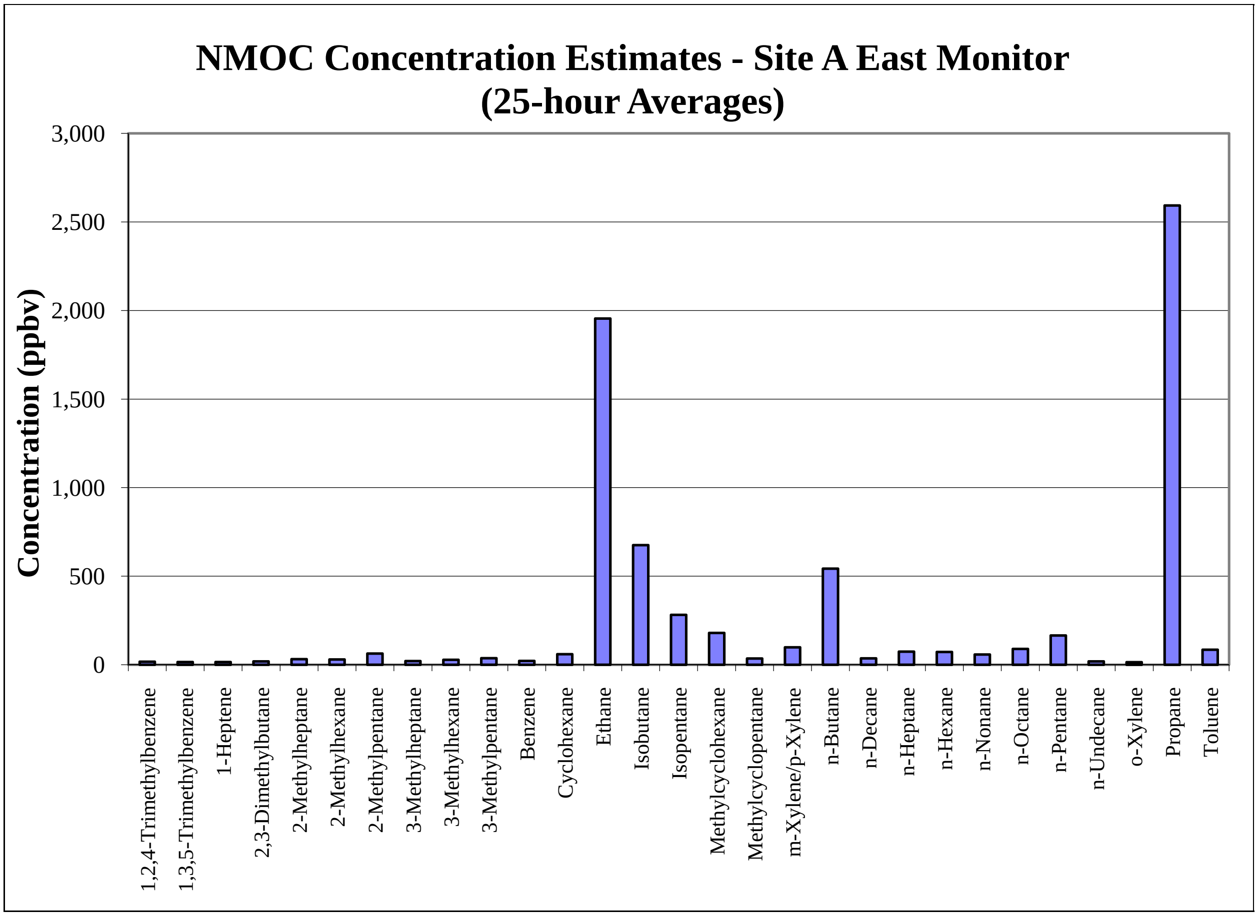


Figure 44. NMOC Concentration Estimates at Site A East Monitor

In summary, the average of the particulate concentrations recorded around the well pad (10.1 μg/m^3) was much lower than the EPA's recommended 24 hour maximum exposure value (35 μg/m^3), and appears to be fairly uniform for this site when compared to the value obtained by the background monitor (10.3 μg/m^3) and the relative percent difference of 2% between the values. Due to a lab error there is no duplicate particulate sample value at this site. The 13-hour average VOC concentration of 3,023 ppbv that was observed appears to be highly dependent on the local meteorological conditions around the site, meaning that if the wind was not blowing in a direction that pushed the VOC plume toward the monitor concentrations were not recorded. The one-minute maximum VOC concentration observed was 24,854 ppbv. The primary wind direction at this site was from the west to southwest, with an average speed of 5.0 mph. The NMOC concentrations are not uniform for this site, as the average of the concentrations around the well pad is much larger than the values recorded by the background monitor. The well pad averages for SNMOCs, unknowns and TNMOCs were 8,761, 1,025, and 9,790 ppbC, respectively, while the background monitor concentrations were 708, 55 and 763, respectively. This gives an average relative percent difference of 174% between the background and well pad monitors. There are also no data for the duplicate NMOC samples due to a lab error.

5.2.2 SITE C

Site C was located approximately 2 miles southwest of Silt. It is slightly to the east of drilling Site D. As with the previously mentioned sites, there were several actively producing wells around the sampling location, many located directly to the south of this site. In addition, there were more active wells to the E, SE, W and N of the site. Figure 45 shows the locations of the samplers with respect to the wells associated with this particular pad. At this site, the duplicate NMOC and particulate samplers, as well as the meteorological station and continuous VOC analyzer, were located at the northern sampling area. The background site was located approximately 1/3 of a mile directly to the west of the well pad site. The particulate samplers were in operation from noon on 7/8/2008 to noon on 7/9/2008. The NMOC samples were taken from approximately 11:00 on 7/8/2008 to approximately 13:00 on 7/9/2008. The VOC samples were taken from approximately 11:00 on 7/8/2008 to 13:00 on 7/9/2008. Table 26 lists the coordinates of each sampler location, and the instruments housed at each site.

Figure 45. Site C Sampling Locations and Surrounding Wells

Table 26. Site C Instrument Locations

Site	Sampling Location	Latitude	Longitude	Instrument Types
C	North (N)	39.509033°	107.667883°	NMOC (x2), VOC, MET, PM2.5 (x2)
	South (S)	39.507433°	107.667667°	NMOC, $PM_{2.5}$
	East (E)	39.508000°	107.667017°	NMOC, $PM_{2.5}$
	West (W)	39.508267°	107.669517°	NMOC, $PM_{2.5}$
	Control (C)	39.508350°	107.674133°	NMOC, $PM_{2.5}$

Figure 46 shows the $PM_{2.5}$ concentrations obtained over a 24-hour sampling period. The particulate concentrations seen at Site C are in the same range as those that were observed at Site A. They ranged from 6.5 $\mu g/m^3$ at the lowest to 9.2 $\mu g/m^3$ at the highest around the pad. The average over the entire well pad was 6.6 $\mu g/m^3$, while the concentration at the background site was 6.9 $\mu g/m^3$. The site map for this well pad shows the production tanks and associated equipment, as well as the gas meter station and the reserve pit to be located along the western boundary of the pad. The western monitor observed the lowest concentrations, while the eastern monitor recorded the highest.

The northern site housed the duplicate particulate samplers at Site C. As can be seen from Figure 46, both samplers observed concentrations that were very similar, with values of 7.8 and 7.5 $\mu g/m^3$. This gives a relative percent difference of approximately 4%. It appears as though the particulate concentrations observed at Site C are more indicative of background $PM_{2.5}$ concentrations for the area, as the average concentration for the well pad was less than the concentration seen at the background site.

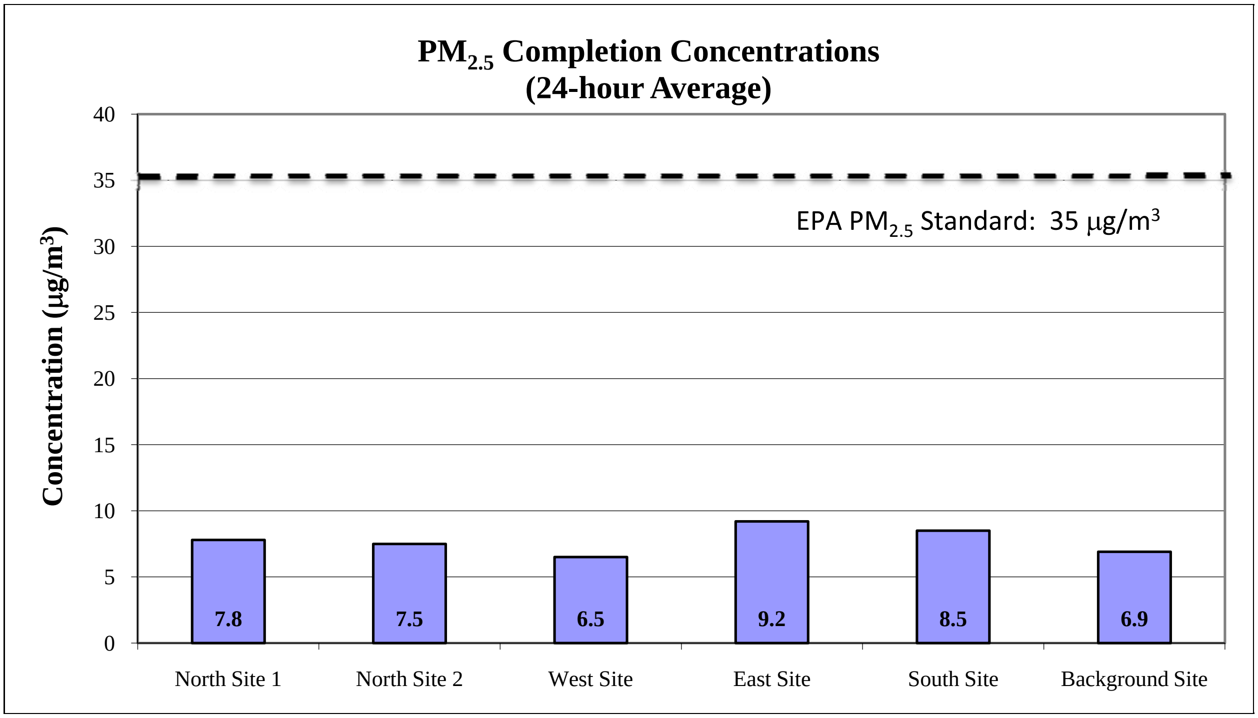


Figure 46. $PM_{2.5}$ Concentrations at Site C

Graphs of the wind speed, wind direction and concentration frequencies are shown in Figure 47, Figure 48 and Figure 49. These graphs indicate that the primary wind direction observed at Site C was from an easterly direction. The majority of the wind came from NE, ENE and SE directions. Most frequently, VOC concentrations were detected simultaneously with winds from the southeasterly direction, while little to no concentrations were detected when winds were from the northeasterly direction. Only 7% of the time was there no wind or concentration detected. During 39% of the time there was both wind and a VOC concentration detected, while there was no wind and a concentration detected 31% of the time, and wind with no concentration detected 23% of the time.

The large VOC concentration spikes appear to occur at approximately the same time as there were winds from the southwest. According to the pad layout map, the production tanks were in a southwesterly direction from the monitors located at the northern site. This would seem to indicate that the VOC concentrations seen were due in large part to the production tanks. Though there was only a small amount of wind coming from the southwest, it was definitely associated with the VOC concentration increases seen at the VOC monitor housed at the northern sampling area, as is evidenced by the 0% frequencies of no VOC concentration plotted in Figure 47, when the winds were from the west to south. In other words, there was never a time when the wind was from the west to the south that there were no VOC concentrations detected. The largest concentration spike of 5,771 ppbv was associated with no measurable wind speed. The site activity log shows that the first well began flowing to the tanks at approximately 10:30 on 7/8/2008, and that from that time until the end of the sampling period there was at least one well flowing to the tank at any given time.

There appears to be an anti-correlation between wind speed and VOC concentrations—as the wind speed increases, the concentrations decrease. The data for Site C shows periods of large VOC activity interspersed with periods of high winds and little to no VOC activity. When the wind speeds have died down to less than 5 mph, the VOC concentration spikes to over 5,500 ppbv. When the winds are 10 mph or more, however, the VOC concentration is at or near zero. The average VOC concentration observed throughout the duration of sampling was 126 ppbv, with an average wind speed of 2.7 mph. This concentration average is much less than what was seen at Site A.

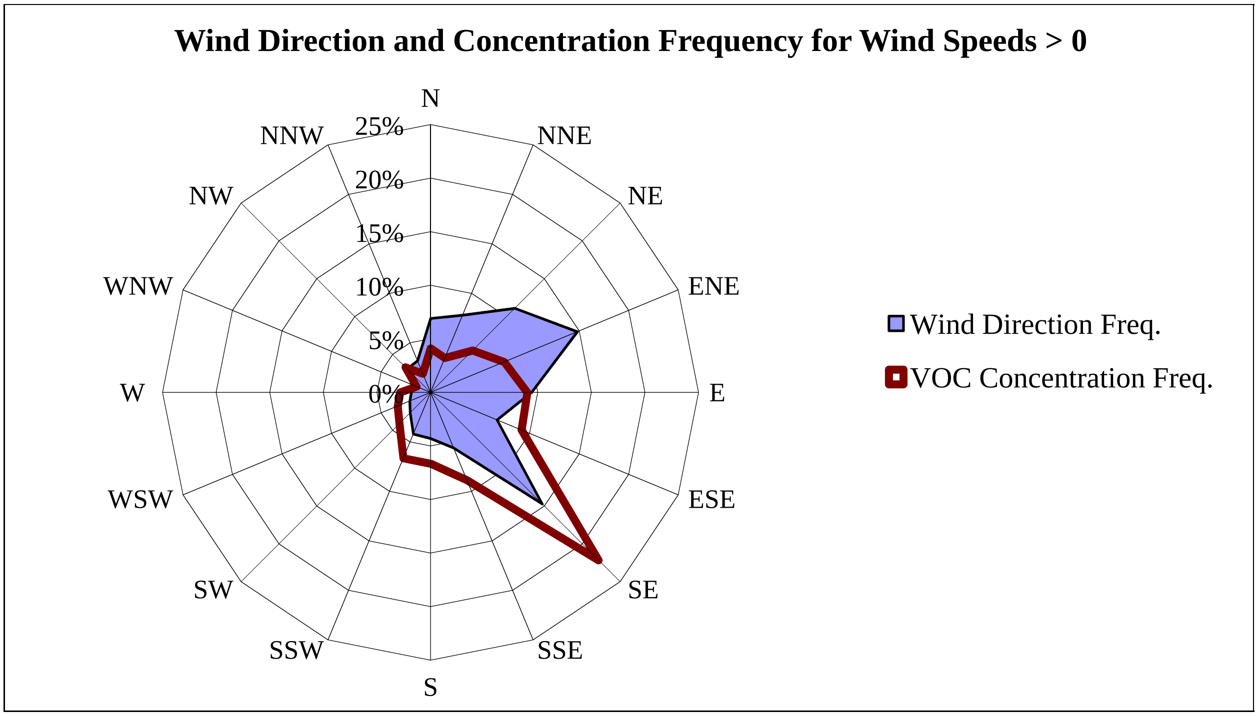


Figure 47. Wind Direction and VOC Concentration Detection Frequencies for Site C

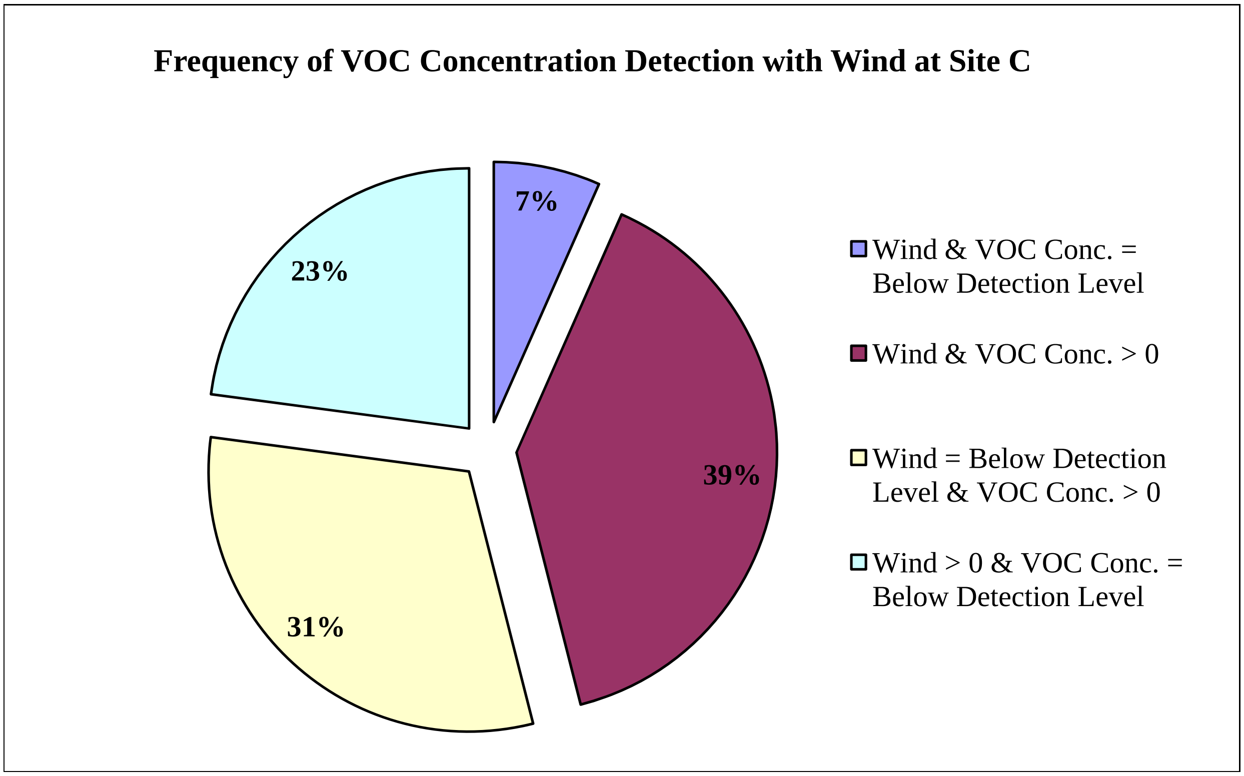


Figure 48. Frequency of VOC Concentration Detection with Measured Wind Speed at Site C

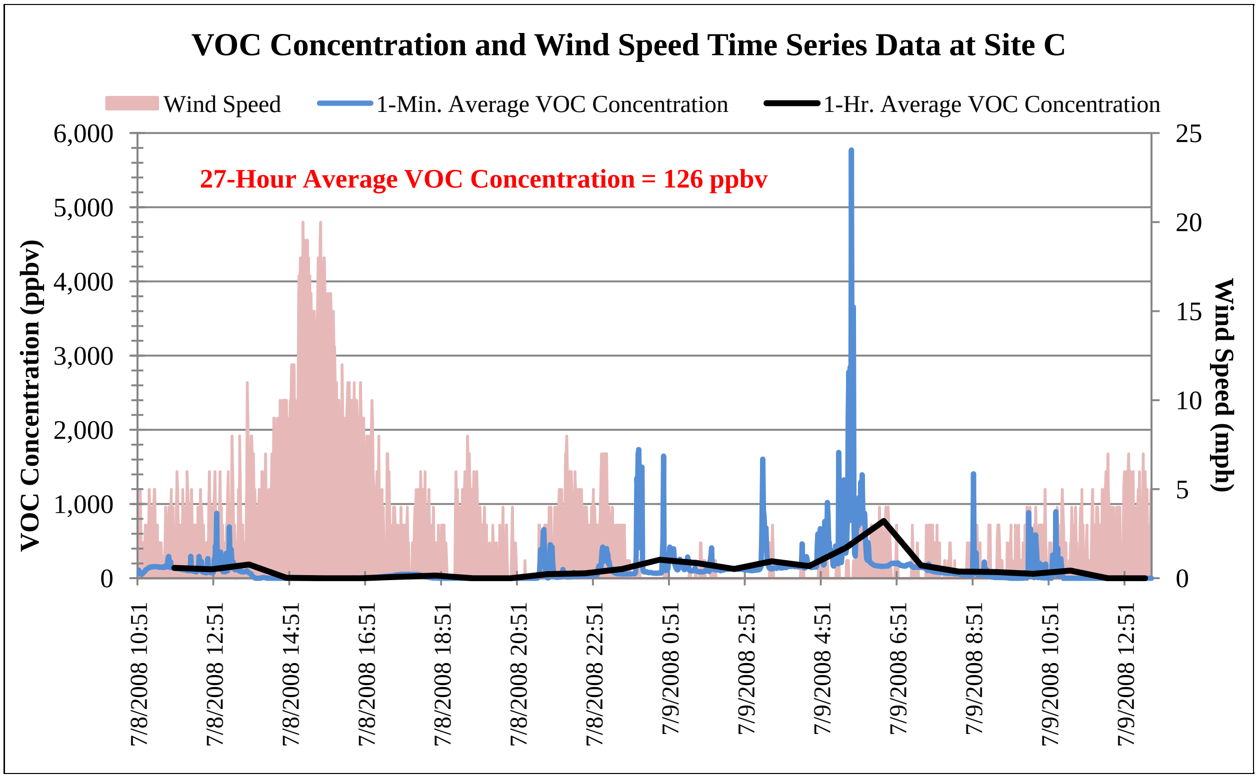


Figure 49. Time Series Data for VOC Concentration and Wind Speed at Site C

Table 27. Maximum and Average VOC Concentrations

Maximum VOC Concentration (taken from 1 minute avgs.)	**Average VOC Concentration (averaged over 27 hours)**
5,771 ppbv	126 ppbv

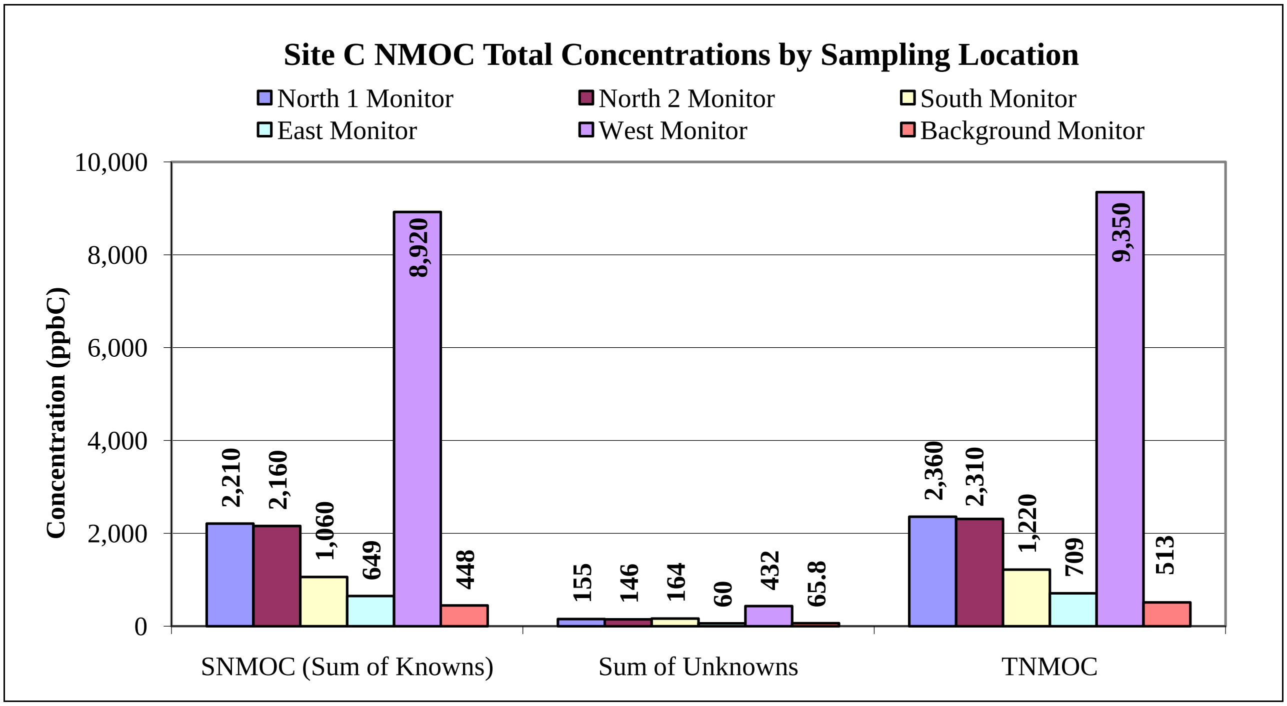


Figure 50. Site C NMOC Concentrations by Sampling Location

Table 28. Well Pad Avg. and Background Monitor NMOC Concentrations and RPD

	Well Pad Avg. Concentration (26 to 27-hr. avg.) ppbC	**Background Monitor Concentration (26-hour avg.) ppbC**	**RPD %**
SNMOC	3,000	448	148
Sum of Unknowns	191	66	97
TNMOC	3,190	513	145

The NMOC samplers were in operation at the same time that the continuous VOC analyzer detected the large concentration spikes, though they were not all run for the same amount of time. Three of the samplers, the two north samplers and the west sampler, were run for 27 hours, while the remaining samplers were all run for 26 hours. Interestingly enough, however, the NMOC monitors at the northern site did not show the highest NMOC concentrations. The western site did, which is odd, because the western site showed the least amount of particulates. Figure 50 shows the graphs of the SNMOC, unknown and TNMOC concentrations obtained at each of the sampling locations. The northern site's concentrations were the second highest, but the concentrations at the western monitor were more than four times greater. In light of a primarily easterly type wind, however, the high concentrations at the west site are logical, especially considering that the site diagram showed production tanks located in the northwest corner of the well pad.

The average SNMOC concentration observed was at 3,000 ppbC. The average TNMOC and unknown concentrations were 3,190 and 191 ppbC respectively. These averages are much larger than those observed at the background site. They are slightly more in line with the averages obtained at the Site A, however. The average unknown concentration percentage for the well pad was approximately 8%, which is slightly less than the percentage of 13% seen at the background site. The background site did record the lowest NMOC concentrations seen.

The average SNMOC concentration of 3,000 ppbC obtained for this site was, again, much higher than the average obtained for the 2006 Front Range study at 371 ppbC. The TNMOC average of 3,190 ppbC was also much higher than the 2006 average of 913 ppbC. The unknown concentrations were again larger for the Front Range study with its 58% value versus the 8% value for this site.

The large NMOC concentrations seen at the west site were due to the easterly winds blowing the pollutants from the productions tanks toward the sampler. There were only 13 compounds whose concentrations are listed as estimates at the western site because their values were above the upper detection limit of the laboratory equipment. The highest values were exhibited again by ethane and propane at approximately 880 and 610 ppbv. Isobutene and n-butane had estimated values above 200 ppbv, and isopentane and n-pentane had values above 100 ppbv. The remaining compounds all had values less than 100 ppbv. A graph of their estimated concentration data can be seen in Figure 51. Of the 47 remaining detectable compounds, methylcyclopentane had the highest concentration at approximately 20 ppbv. All other detected compounds were less than 10 ppbv. There were 18 non-detectable/non-reportable compounds, with isobutene/1-butene co-eluting with another compound.

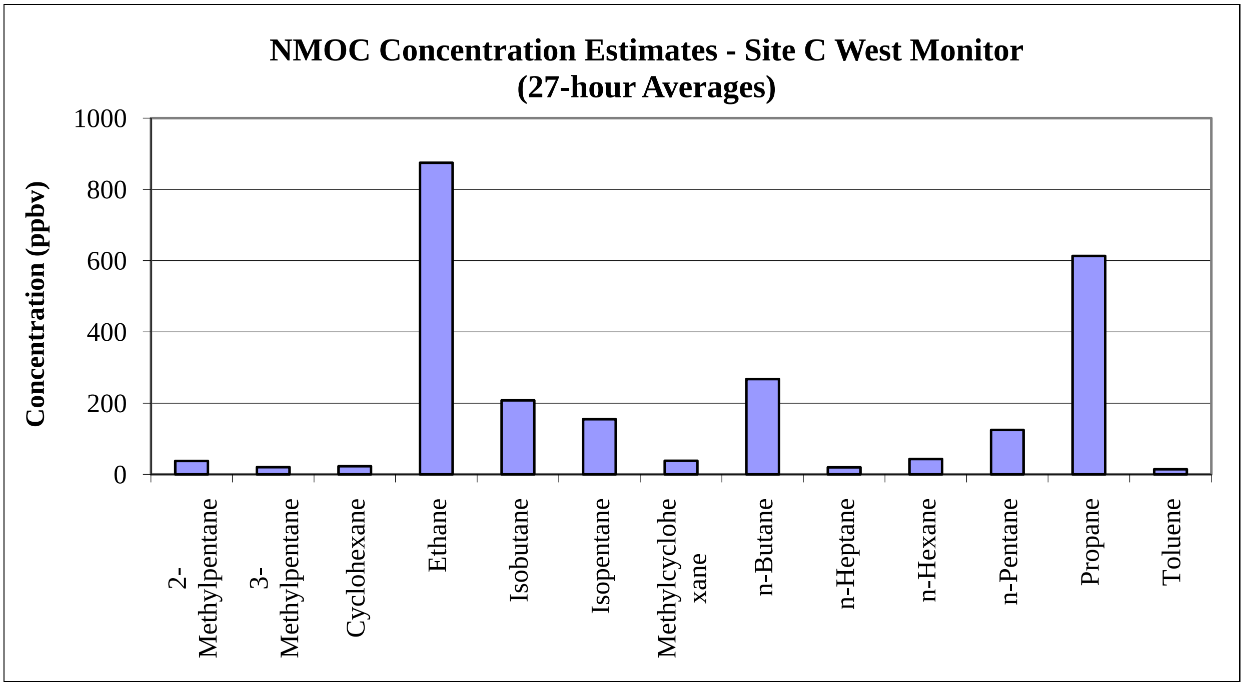


Figure 51. NMOC Concentration Estimates at Site C West Monitor

The northern sites did not have concentrations that were as high as those at the west site, but they were still very high. The SNMOC concentrations were approximately 2,200 ppbC and the TNMOC concentration was approximately 2,400 ppbC. Again, as with the west site, the majority of the concentrations are not due to unknown compounds. Unlike the 13 concentration estimates seen at the western site, this site had only 6 compounds with estimated concentrations. The highest values were from ethane at approximately 300 ppbv and propane at approximately 175 ppbv. The remaining compounds were isobutane, isopentane, n-butane and n-pentane. Their estimated concentrations can be seen in Figure 52. The values obtained at the secondary north site can be seen in Figure 53.

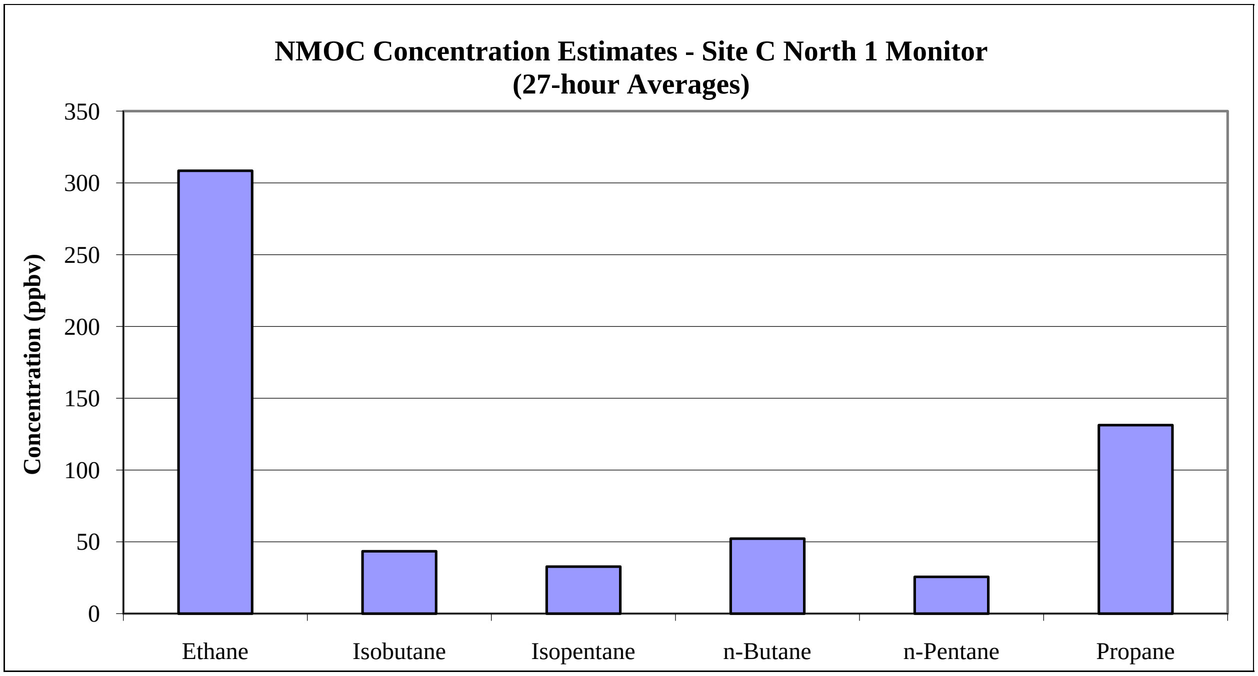


Figure 52. NMOC Concentration Estimates at Site C North 1 Monitor

As with the western site, the northern sites had another compound co-elute with the isobutene/1-butene, making its results unreportable. There were 45 detected compound at the primary sampler and 51 at the secondary sampler. There were 26 non-detectable/non-reportable compounds at the primary site and only 20 at the secondary site.

Table 29. Duplicate NMOC Samples and RPDs

ANALYTE	RESULT 1 (ppbC)	RESULT 2 (ppbC)	RPD (%)
1,2,3-Trimethylbenzene	0.253	0.238	6
1,2,4-Trimethylbenzene	2.87	2.67	7
1,3,5-Trimethylbenzene	2.94	2.79	5
1-Dodecene	0.11	0.117	6
1-Heptene	7.19	6.92	4
1-Hexene	0.119	0.078	42
1-Nonene	0.5	0.448	11
1-Octene	0.285	0.198	36
1-Pentene	0.142	0.179	23
1-Undecene	0.144	0.145	1
2,2,3-Trimethylpentane	1.58	1.61	2
2,2-Dimethylbutane	7.75	7.54	3
2,3,4-Trimethylpentane	0.173	0.144	18
2,3-Dimethylbutane	13.6	13.4	1
2,3-Dimethylpentane	4.87	4.75	2
2,4-Dimethylpentane	3.62	3.52	3
2-Methylheptane	8.39	8.14	3
2-Methylhexane	14.5	14	4
2-Methylpentane	57.6	56.5	2
3-Methylheptane	4.88	4.68	4
3-Methylhexane	13.9	13.4	4
3-Methylpentane	30.8	30.1	2
4-Methyl-1-pentene	0.347	0.167	70
Acetylene	0.558	0.536	4
a-Pinene	1.57	1.56	1
Benzene	13	12.5	4
cis-2-Butene	0.098	0.092	6
cis-2-Hexene	0.424	0.436	3
Cyclohexane	34.5	33.7	2
Cyclopentane	7.59	7.48	1
Cyclopentene	0.21	0.274	26
Ethane	615	604	2
Ethylbenzene	1.74	1.62	7
Ethylene	1.2	1.2	0
Isobutane	174	170	2
Isopentane	164	163	1
Isoprene	1.15	1.14	1
Isopropylbenzene	0.468	0.43	8
m-Diethylbenzene	0.324	0.304	6
Methylcyclohexane	62.8	60.8	3
Methylcyclopentane	30.9	30.2	2
m-Ethyltoluene	1.57	1.51	4
m-Xylene/p-Xylene	16.4	15.7	4
n-Butane	208	203	2
n-Decane	6.04	5.8	4

ANALYTE	RESULT 1 (ppbC)	RESULT 2 (ppbC)	RPD (%)
n-Dodecane	4.07	3.62	12
n-Heptane	31.1	30.1	3
n-Hexane	64.6	62.3	4
n-Nonane	8.89	8.43	5
n-Octane	18.8	18.1	4
n-Pentane	127	126	1
n-Propylbenzene	0.526	0.512	3
n-Tridecane	1.58	1.01	44
n-Undecane	5.13	4.87	5
o-Ethyltoluene	1.14	1.06	7
o-Xylene	2.95	2.8	5
p-Ethyltoluene	1.19	1.2	1
Propane	392	384	2
Propylene	0.577	0.543	6
SNMOC (Sum of Knowns)	2210	2150	3
Sum of Unknowns	155	152	2
TNMOC	2360	2310	2
Toluene	25.4	24.4	4

The southern site also experienced elevated NMOC levels. The TNMOC concentration was just over 1,200 ppbC, and the SNMOC concentration was around 1,050 ppbC. There were a larger percentage of unknowns for this site, with a value of 13%. There were 22 non-detectable/non-reportable compounds in addition to the isobutene/1-butene co-eluting with another compound, and the 53 detected compounds. At this site the only estimated concentrations were from ethane and propane, which had values of 90 ppbv and 52 ppbv, respectively. The remaining detected compounds all had concentrations that were under 25 ppbv.

Like the southern site, the eastern site had only two compounds with estimated concentrations, ethane (72 ppbv) and propane (42 ppbv). There were 27 non-detectable/non-reportable compounds and no co-eluting compounds. The remaining 49 detected compounds all had values that were less than 18 ppbv. The SNMOC and TNMOC concentrations were elevated, but not nearly to the levels seen at the previous sites with an SNMOC value of roughly 650 ppbC, a TNMOC value of approximately 700 ppbC and an unknown concentration of around 60 ppbC, or 8% of the total NMOCs. These values are all less than those obtained in the 2006 Front Range study.

The background site exhibited the lowest NMOC values recorded for this site. Only ethane had an estimated concentration at 51 ppbv. Isobutene did co-elute with another compound though, and was not reported along with 32 other compounds that were not detected and subsequently not reported. There were 44 detected compounds, with propane having the highest concentration at nearly 30 ppbv. The next closest values were around 10 ppbv. The TNMOC and SNMOC concentrations were much lower than any of the other sites, with values of roughly 500 and 450 ppbC respectively. The approximate 66 ppbC unknown concentration leads to a value of 13% in regards to the total NMOC concentrations. This value ties it with the south site for the highest percentage of unknown compounds.

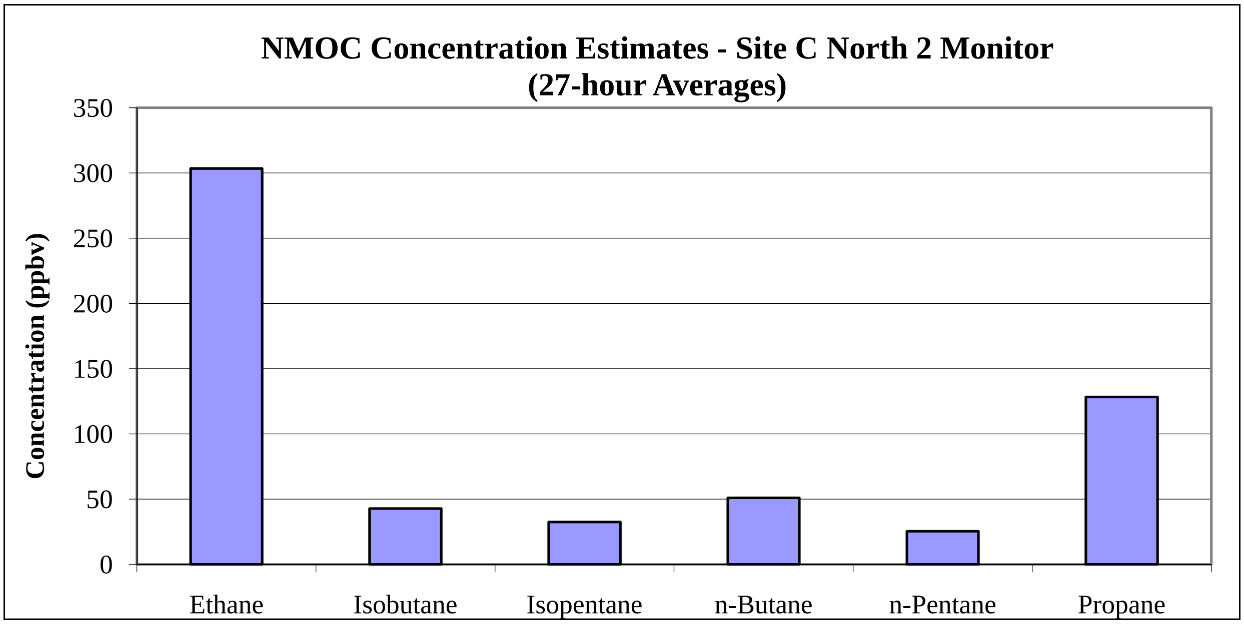


Figure 53. NMOC Concentration Estimates at Site C North 2 Monitor

In summary, the average of the particulate concentrations recorded around the well pad (6.6 μg/m^3) was much lower than the EPA's recommended 24 hour maximum exposure value (35 μg/m^3), and appears to be fairly uniform for this site when compared to the value obtained by the background monitor (6.9 μg/m^3) and the relative percent difference of 4% between the two values. The duplicate samples taken also show good agreement with a relative percent difference of 4% between the samplers. The 24-hour average VOC concentration of 126 ppbv that was observed appears to be highly dependent on the local meteorological conditions around the site, meaning that if the wind was not blowing in a direction that pushed the VOC plume toward the monitor concentrations were not recorded. The one-minute maximum VOC concentration observed was 5,771 ppbv. The primary wind direction at this site was from the northeast to southeast, with an average speed of 2.7 mph. The NMOC concentrations were not uniform for this site, as the average of the concentrations around the well pad is not similar to the values recorded by the background monitor. The well pad averages for SNMOCs, unknowns and TNMOCs were 3,000, 191, and 3,190 ppbC, respectively, while the background monitor concentrations were 448, 66 and 513, respectively. This gives an average relative percent difference of 130% between the background and well pad monitors. The duplicate NMOC samples showed good agreement with an average relative percent difference of 3% between the samplers.

5.2.3 SITE E

This site was located to the south of the Parachute/Grand Valley area, in the vicinity of a populated neighborhood. This is yet another sampler that was surrounded by many active wells. Figure 54 shows the locations of the samplers in relation to the wells associated with this pad, and other wells in the surrounding locality. The figure clearly shows four additional well pads to the south and western areas of Site E. The well pad is situated on the leading edge of a mesa. The duplicate NMOC and $PM_{2.5}$ analyzers, as well as the meteorological station and the continuous VOC sampler were housed at the eastern sampling site. According to the site diagram, the production tanks were located just to the north of the southern sampling site. The VOCs were sampled from approximately 09:00 on 7/22/2008 to approximately 13:00 on 7/23/2008. NMOC samples were taken from around 11:00 on 7/22/2008 to around 13:00 on 7/23/2008. The $PM_{2.5}$ samplers were run from noon on 7/22/2008 to noon on 7/23/2008. The background site was located due west of the well pad, approximately one mile from it. Table 30 lists the coordinates of each sampling location, and the analyzers that were placed at each.

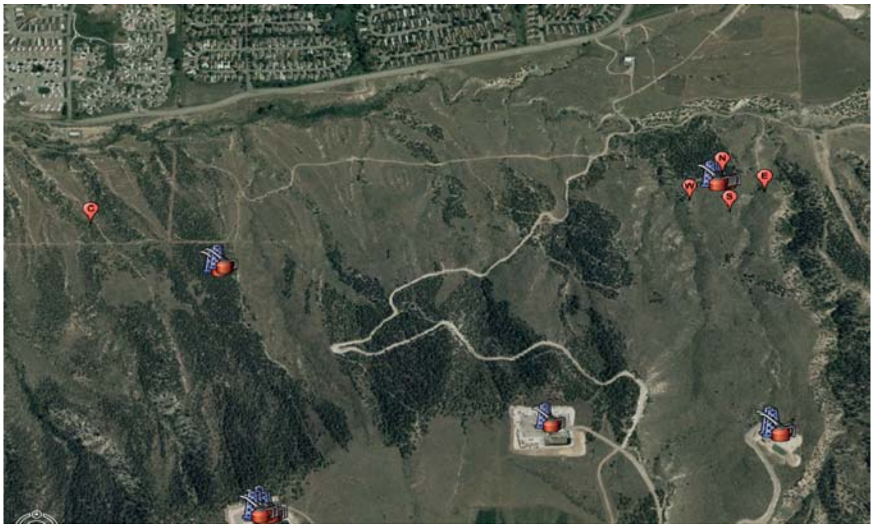


Figure 54. Site E Sampling Locations and Surrounding Wells

Table 30. Site E Instrument Locations

Site	Sampling Location	Latitude	Longitude	Instrument Types
E	North (N)	39.421783°	108.032550°	NMOC, $PM_{2.5}$
	South (S)	39.420650°	108.032450°	NMOC, $PM_{2.5}$
	East (E)	39.421267°	108.031333°	NMOC (x2), VOC, MET, $PM_{2.5}$ (x2)
	West (W)	39.420983°	108.033550°	NMOC, $PM_{2.5}$
	Control (C)	39.420450°	108.051367°	NMOC, $PM_{2.5}$

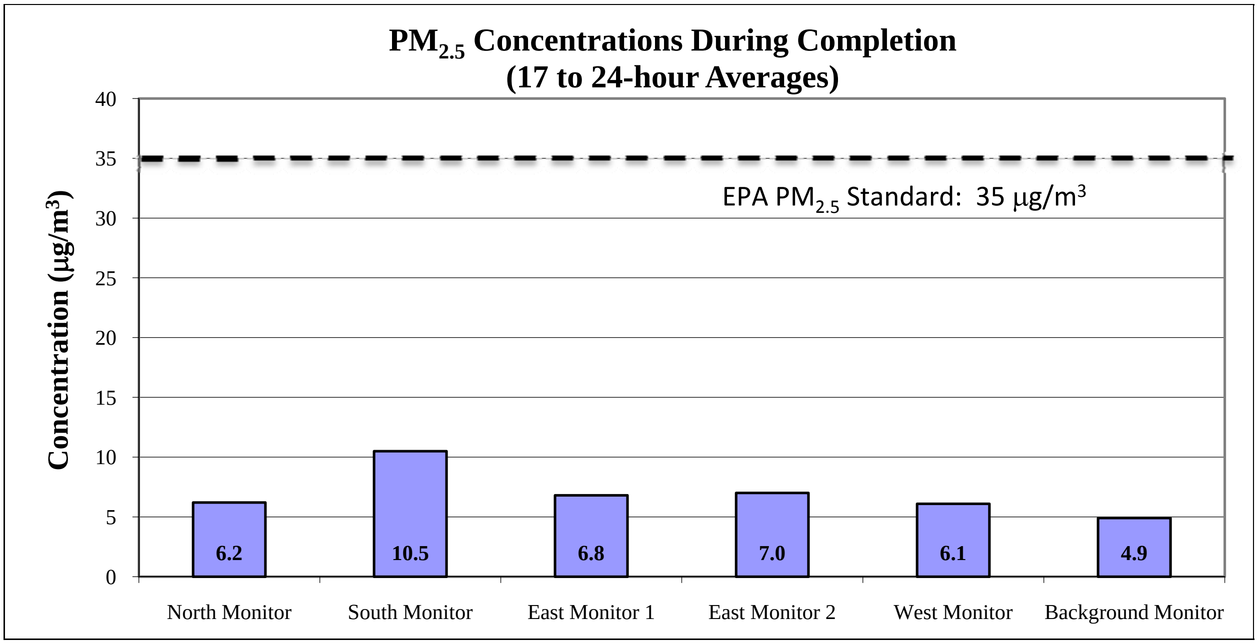


Figure 55. $PM_{2.5}$ Completion Concentrations at Site E

The particulate data are shown in Figure 55. At this location not all of the samplers were run for the standard 24 hour sampling period. The background, east 2, north and south monitors were run for less than 24 hours, while the east 1 and west monitors were run for 24 hours. The background sampler was run for 17 hours, while the remaining samplers were run for 19, 19, and 18 hours each, respectively. It is unclear why the samplers were not run for the entire period. The data show that although the northern site was not run for the standard sampling period, it had the highest concentration of particulates during the sampling. Its value of 10.5 μg/m^3 is larger than the next closest value at the secondary eastern site of 7.0 μg/m^3, which was also not run for the entire sampling period. The average particulate concentration for the well pad is 7.3 μg/m^3, which is higher than the value observed at the background site of 4.9 μg/m^3. The concentrations recorded at the duplicate samplers were very similar at 6.8 and 7.0 μg/m^3, respectively, even though they were not run for the same period of time.

The prevailing wind at the southern monitoring station was from a southwesterly direction. There was also a smaller percentage from the north and southeast, the majority came from the southwest. This is logical when considering that this site sat on the side of a mesa and the southern site was situated such that it was higher in elevation than the other sites. It was located near the outlet of a “gully” on the side of the mesa. The gully goes in a southwesterly direction and it makes sense that most of the wind would be funneled through there. Figure 56 shows the wind and concentration detection frequency data for Site E.

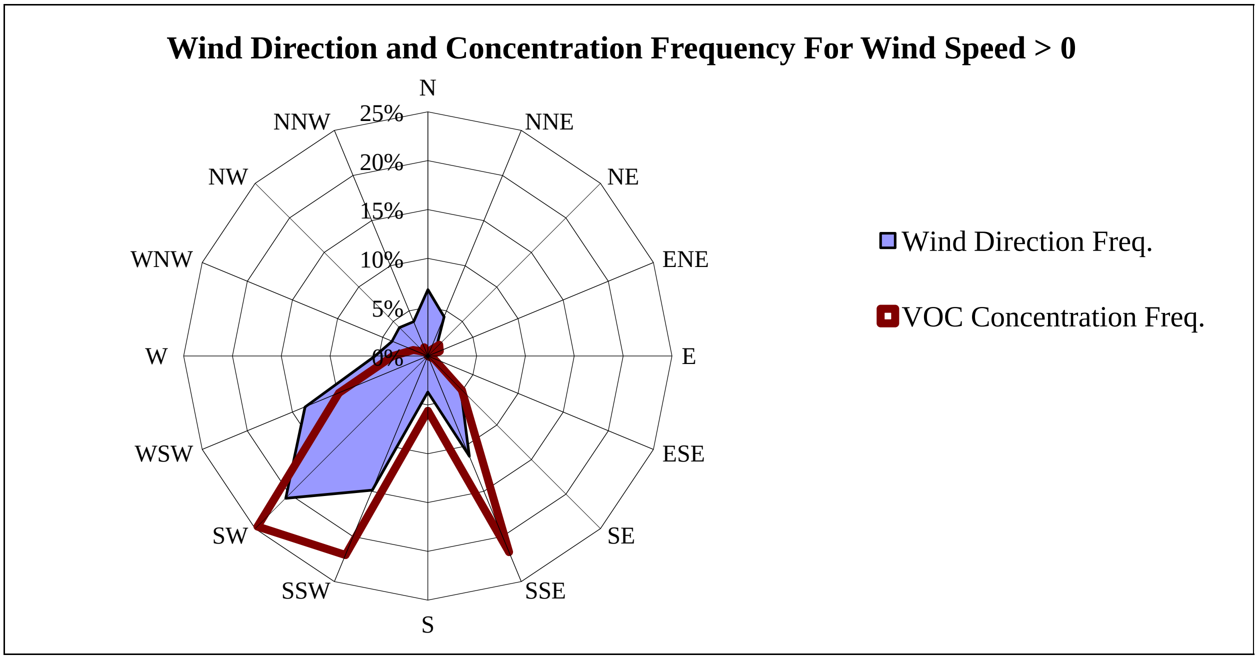


Figure 56. Wind Direction and Concentration Detection Frequencies at Site E

What this figure shows is that when there was a VOC concentration detected with a simultaneous measurable wind speed, the primary directions the wind were blowing from at that time were the SW, SSW and SSE. When the wind was out of a northerly direction there was generally no VOC concentration detected. It should be noted that there are two other drilling pads in operation near the southern site – one on top of the mesa and another further south of the site, and higher in elevation. A better illustration of the concentration/wind speed detection frequency concept is seen in Figure 57. It gives the breakdown of the frequency with which a VOC concentration was detected in relation to a simultaneous detection of wind speed. Only 7% of the time was there no wind speed or concentration detected. For 18% of the time there was both a wind speed and a VOC concentration detected. The remaining 75% of the time is split between wind and no concentration (61%), and concentration and no wind (14%). This means that for the duration of the sampling period, the majority of time the wind blew, there was no VOC concentration detected.

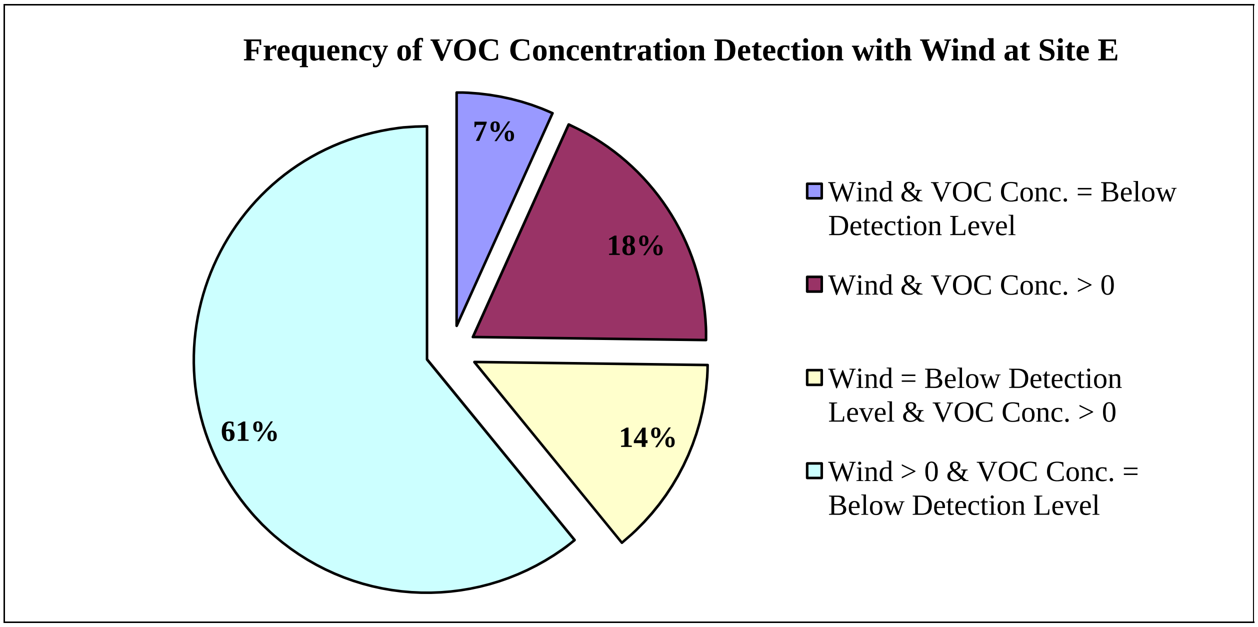


Figure 57. Frequency of Concentration Detection with Measurable Wind Speed at Site E

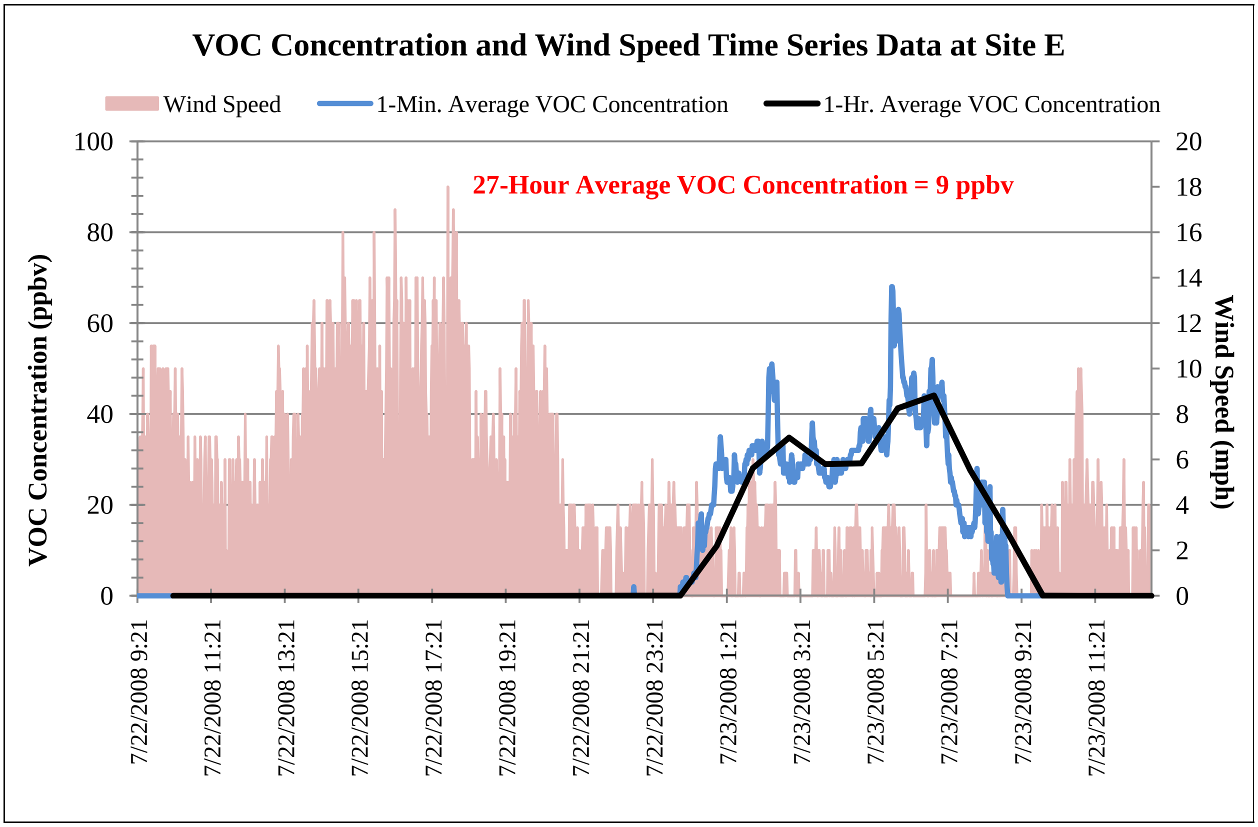


Figure 58. Time Series Data for VOC Concentration and Wind Speed at Site E

Table 31. Maximum and Average VOC Concentrations

Maximum VOC Concentration (taken from 1 minute avgs.)	Average VOC Concentration (averaged over 27 hours)
68 ppbv	9 ppbv

Figure 58 is a graph of the time series data obtained for VOC concentration and wind speed. It shows that early in the sampling period, there were wind speeds that were significantly larger than 5 mph, and there were no VOC concentrations detected then. Once the winds dropped back off to less than 5 mph for a short time, the VOC concentrations quickly began rising. The highest concentration spike recorded is only near 70 ppbv. The figure shows that there is a period of VOC activity from roughly midnight to 09:00 on 7/23/2008. The average VOC concentration recorded over the duration of the sampling period was 9.3 ppbv, with an average wind speed of 4.1 mph.

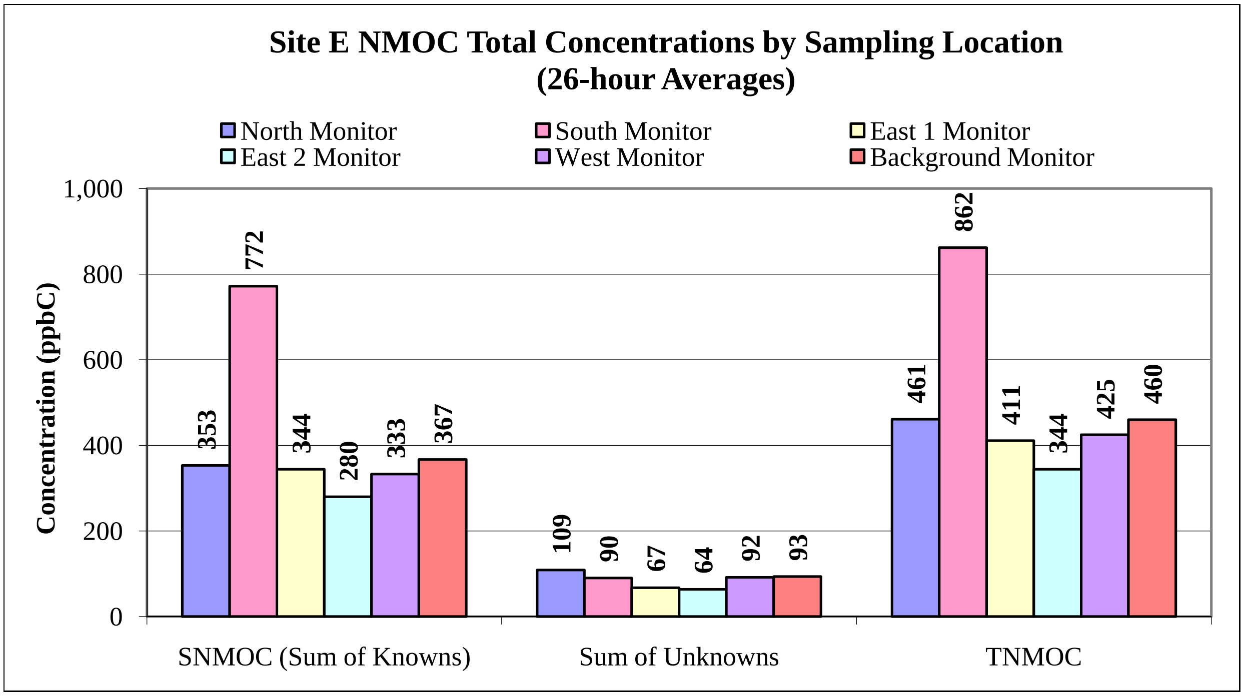


Figure 59. NMOC Total Concentrations by Sampling Location at Site E

Table 32. Well Pad Avg. and Background Monitor Concentrations and RPDs

	Well Pad Avg. Concentration (26-hour) ppbC	Background Monitor Concentration (26-hour) ppbC	RPD %
SNMOC	416	367	13
Sum of Unknowns	84	93	10
TNMOC	501	460	9

The NMOC samplers at Site E were all run for 26 hours. Figure 59 shows the SNMOC, unknown and TNMOC concentrations obtained at Site E. The southern sampler recorded the highest overall concentration at 862 ppbC, which was nearly double what the next closest concentration was at the north site (461 ppbC). The background site recorded the third highest TNMOC concentration, with a value of 460 ppbC. It recorded the second highest SNMOC value, however, at 367 ppbC. The average SNMOC, unknown and TNMOC concentrations seen at the well pad were 416, 84, and 501 ppbC, respectively. All average concentrations at this site, except for the unknown average, were higher than the values recorded at the background site, but only by a small amount. The average percentage of unknowns for the pad was 17%, versus 18% at the background site.

The site set up was such that there were four 300-barrel tanks near the southern sampler. The wind was typically from the southwest, so it is possible that the high concentrations seen at the southern site were due to the presence of the production tanks near the sampler. An additional source could be attributed to the presence of 6 well pad sites at the top of the mesa this site was situated on. The majority of these sites were in a southwesterly direction from this particular pad. There were also a couple of well pads to the southeast of this pad as well. The VOC concentration increases all occurred when the wind was from the southeast or southwest area. It may well be that the high NMOC concentrations seen at other sites and not at this one, were not seen because the tanks were positioned such that the wind blew the concentrations out of range of the northern sampling site.

The average SNMOC concentration of 416 ppbC is somewhat larger than that same concentration recorded during the 2006 Front Range study (371 ppbC). That is where the similarities end, however. The unknown concentration in 2006 is more than 6 times higher than that at the completion site, with values of 542 and 73 ppbv, or 58% and 18%, respectively. The 2006 TNMOC concentration is nearly double at 913 versus 501 ppbC.

The primary eastern site's highest speciated NMOC concentration was due to ethane at roughly 70 ppbv and propane at around 15 ppbv. The ethane concentration is an estimate, as it was above the lab instrument's upper detection level. There were 27 of the 78 compounds tested for that were non-detectable/non-reportable. The secondary eastern site also had an estimated ethane concentration, but that value was just over 50 ppbv. Again, propane was second at this site with roughly 12 ppbv. In addition to the 1 estimated compound concentration, there were 29 non-detectable/non-reportable compounds at the secondary site.

Table 33. Duplicate NMOC Sample Results and RPDs

ANALYTE	RESULT 1 (ppbC)	RESULT 2 (ppbC)	RPD (%)
1,2,3-Trimethylbenzene	0.176	0.147	18
1,2,4-Trimethylbenzene	0.81	0.707	14
1,3,5-Trimethylbenzene	0.645	0.46	33
1-Heptene	1.26	0.919	31
1-Hexene	0.195	0.133	38
1-Pentene	0.167	0.159	5
2,2,3-Trimethylpentane	0.308	0.344	11
2,2-Dimethylbutane	0.829	0.733	12
2,3-Dimethylbutane	1.34	0.996	29
2,3-Dimethylpentane	0.753	0.548	32
2,4-Dimethylpentane	0.598	0.435	32
2-Methyl-1-butene	1.29	1.18	9
2-Methylheptane	1.56	1.12	33
2-Methylhexane	2.34	1.95	18
2-Methylpentane	5.84	4.84	19
3-Methylheptane	1.36	0.901	41
3-Methylhexane	2.34	1.66	34
3-Methylpentane	3.1	2.34	28
4-Methyl-1-pentene	0.292	0.284	3
Acetylene	0.414	0.455	9
a-Pinene	0.471	0.44	7
Benzene	2.37	1.86	24
cis-2-Butene	0.167	0.117	35
Cyclohexane	4.66	3.94	17
Cyclopentane	0.729	0.582	22
Cyclopentene	0.352	0.489	33
Ethane	137	105	26
Ethylbenzene	0.595	0.49	19
Ethylene	0.934	1.2	25
Isobutane	14	10.5	29

ANALYTE	RESULT 1 (ppbC)	RESULT 2 (ppbC)	RPD (%)
Isobutene/1-Butene	8.22	6.75	20
Isopentane	20.8	21.1	1
Isoprene	0.721	1.66	79
m-Diethylbenzene	0.162	0.135	18
Methylcyclohexane	11.3	8.25	31
Methylcyclopentane	3.76	2.72	32
m-Ethyltoluene	0.548	0.472	15
m-Xylene/p-Xylene	4.2	3.28	25
n-Butane	14.6	11.1	27
n-Decane	2.56	2.99	15
n-Dodecane	3.19	5.56	54
n-Heptane	4.73	3.44	32
n-Hexane	6.87	4.8	35
n-Nonane	2.33	1.76	28
n-Octane	4.05	3.04	28
n-Pentane	9.43	7.08	28
n-Propylbenzene	0.214	0.204	5
n-Tridecane	1	1.28	25
n-Undecane	3.83	7.16	61
o-Xylene	0.75	0.625	18
p-Ethyltoluene	0.321	0.227	34
Propane	45.7	35.1	26
Propylene	0.489	0.552	12
SNMOC (Sum of Knowns)	344	280	21
Sum of Unknowns	65.7	61.8	6
TNMOC	410	342	18
Toluene	6.43	5.1	23
trans-2-Butene	0.187	0.281	40
trans-2-Pentene	0.1	0.133	28

The northern site had a propane concentration equivalent to 14 ppbv, and an estimated ethane concentration of 60 ppbv. There were 24 non-detectable/non-reportable compounds. These concentrations are in line with those seen at the eastern site. The southern samplers had an ethane concentration estimate of 230 ppbv, with a propane concentration that was more than double that seen at the other sites (32 ppbv). There were 24 non-detectable/non-reportable compounds. The western site's estimated ethane concentration was 52 ppbv, with a 14 ppbv propane concentration. As with the last two sites, there were 24 non-detectable/non-reportable compounds.

The background site's ethane concentration was 65 ppbv, again an estimate. The propane concentration was 16 ppbv. There were 24 non-detectable/non-reportable compounds. The concentrations recorded at this site were consistently higher than those recorded a the eastern and western sites, but were quite similar to those at the northern site. This site was also near the area where the mesa top well pads were, and likely could have been affected by their presence.

In summary, the average of the particulate concentrations recorded around the well pad (7.3 $\mu g/m^3$) was much lower than the EPA's recommended 24 hour maximum exposure value (35 $\mu g/m^3$), and appears to be somewhat uniform for this site when compared to the value obtained by the background monitor (4.9 $\mu g/m^3$) and the relative percent difference of 39% between the two values. The duplicate samples taken show excellent agreement with a relative percent difference of 3% between the samplers. The 24-hour average VOC concentration of 9 ppbv that was observed appears to be highly dependent on the local meteorological conditions around the site, meaning that if the wind was not blowing in a direction that pushed the VOC plume toward the monitor concentrations were not recorded. The one-minute maximum VOC concentration observed was 68 ppbv. The primary wind direction at this site was from the southwest, with an average speed of 4.1 mph. The NMOC concentrations also seem to be rather uniform for this site, as the average of the concentrations around the well pad is similar to the values recorded by the background monitor. The well pad averages for SNMOCs, unknowns and TNMOCs were 416, 84, and 501 ppbC, respectively, while the background monitor concentrations were 367, 93 and 460, respectively. This gives an average relative percent difference of 11% between the background and well pad monitors. The duplicate NMOC samples showed some agreement with an average relative percent difference of 15% between the samplers.

5.2.4 SITE G

Site G was located just southwest of Parachute, along Interstate 70. It sat between the interstate and the Colorado River. There were other active well sites that were nearby. Figure 60 shows the locations of the samplers as well as some of the nearby wells. The eastern sampling site hosted the duplicate NMOC and $PM_{2.5}$ monitors, as well as the met station and continuous VOC sampler. According to the site diagram, the production tanks and associated facilities were located near the eastern sampler. The VOC samples were taken from approximately 10:00 on 6/18/2008 to approximately 12:30 on 6/19/2008. The NMOC samples were taken from 11:00 on 6/18/2008 to 15:00 on 6/19/2008. The particulate samplers were run from noon on 6/18/2008 to noon on 6/19/2008. The background site was located approximately ¾ of a mile to the southwest of the well pad, along the interstate. Table 34 lists the coordinates of all the samplers, in addition to the instruments used at each location.

Figure 60. Site G Sampling Locations and Surrounding Wells

Table 34. Site G Instrument Locations

Site	Sampling Location	Latitude	Longitude	Instrument Types
G	North (N)	39.431661°	108.070682°	NMOC, $PM_{2.5}$
	South (S)	39.430462°	108.071095°	NMOC, $PM_{2.5}$
	East (E)	39.430899°	108.070200°	NMOC (x2), VOC, MET, $PM_{2.5}$ (x2)
	West (W)	39.431169°	108.071166°	NMOC, $PM_{2.5}$
	Control (C)	39.423029°	108.081411°	NMOC, $PM_{2.5}$

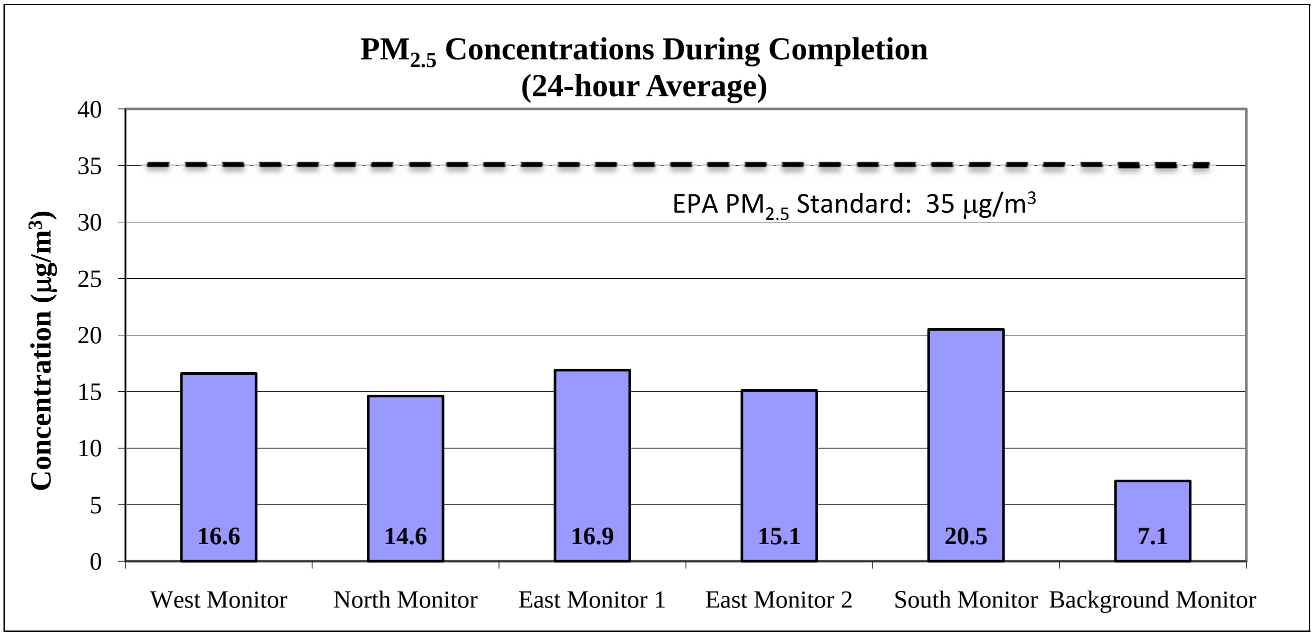


Figure 61. $PM_{2.5}$ Completion Concentrations at Site G

Figure 61 shows the particulate concentrations obtained at Site G. All but one of the samplers was run for the entire 24-hour sampling period. The background site sampler was run for 23.5 hours. It is unclear why this is the case. These concentrations are the highest seen of all the drilling and completion sites. The average over the well pad area is 16.7 $\mu g/m^3$. The concentration at the background site was only 7.1 $\mu g/m^3$, a near 10 $\mu g/m^3$ difference. The highest value recorded was at the southern site (20.5 $\mu g/m^3$). There was some discrepancy between the values obtained from the duplicate samplers. The primary sampler concentration was 16.9 $\mu g/m^3$, while the secondary sampler's concentration was 15.1 $\mu g/m^3$.

The meteorological station recorded the average wind direction to be from a general northeasterly direction. There was also a smaller amount of wind from the southwest direction. It is this wind direction that seems to have the greatest effect on the VOC concentration detection. Any concentration increases seen were associated with winds from the southwesterly direction. When the winds were from the northeast, little to no VOC concentrations were detected. There are 16 sites, each with multiple wells, all within three miles or less of this completion site, and all of which are actively producing oil or natural gas. The wind direction and concentration frequency graph can be seen in Figure 62. As was previously mentioned, the production tanks were near the eastern monitors, so a WSW wind would blow any pollutants to the eastern monitor.

During the study, only 3% of the time was there no wind and no VOC concentration detected. For 23% of the time there was both a wind speed and a VOC concentration value detected. The remaining 73% is split between no wind and a positive concentration (1%) and no concentration and a positive wind speed (72%). Figure 63 illustrates this more clearly.

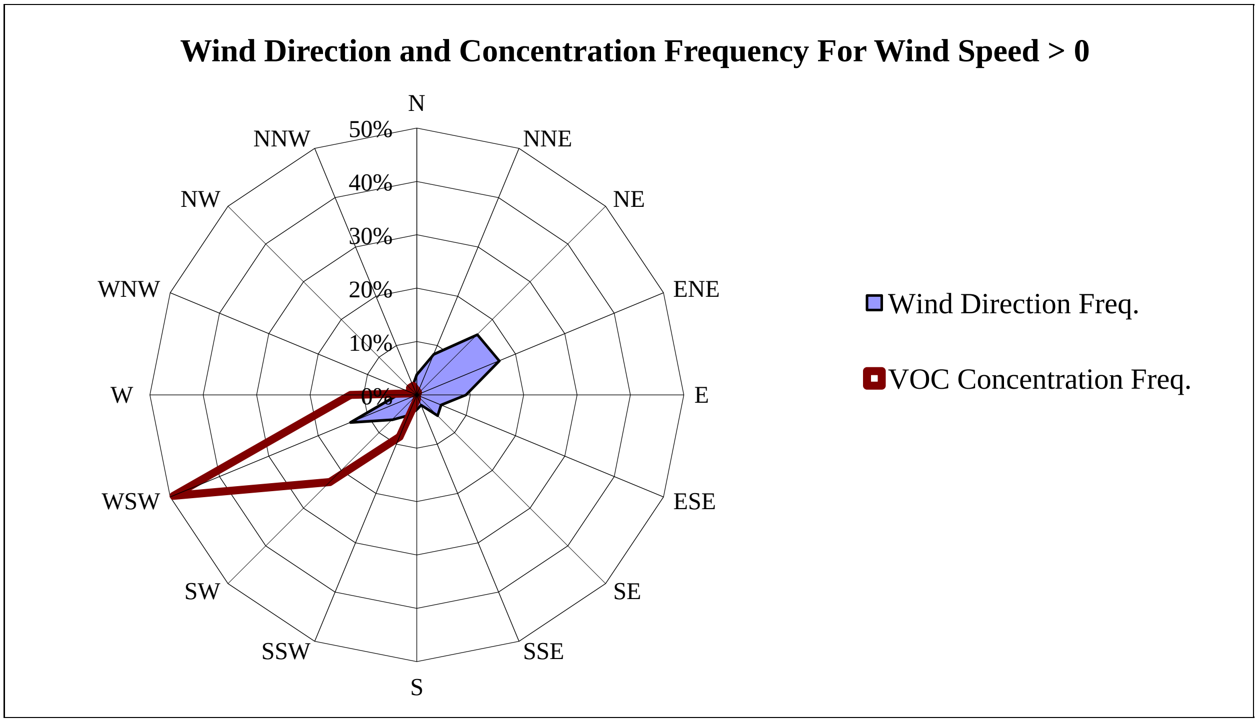


Figure 62. Wind Direction and VOC Concentration Detection Frequency for Site G

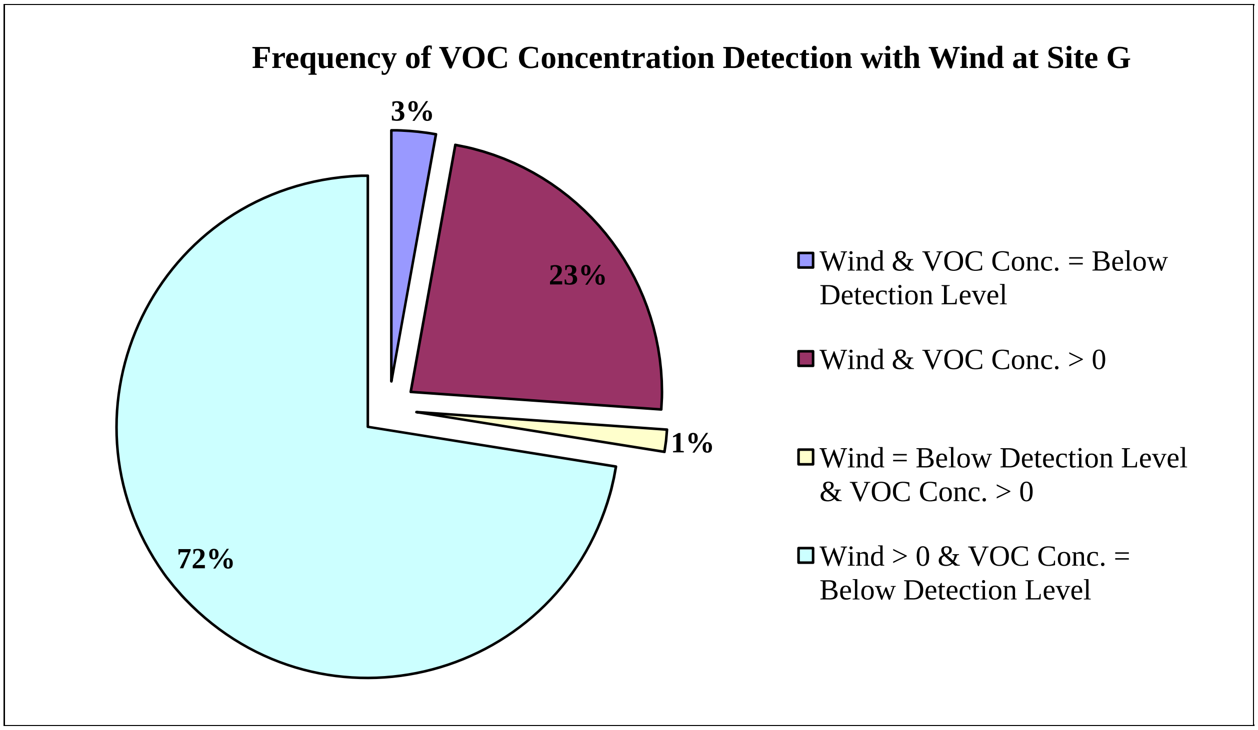


Figure 63. Frequency of Concentration with Measurable Wind Speed at Site G

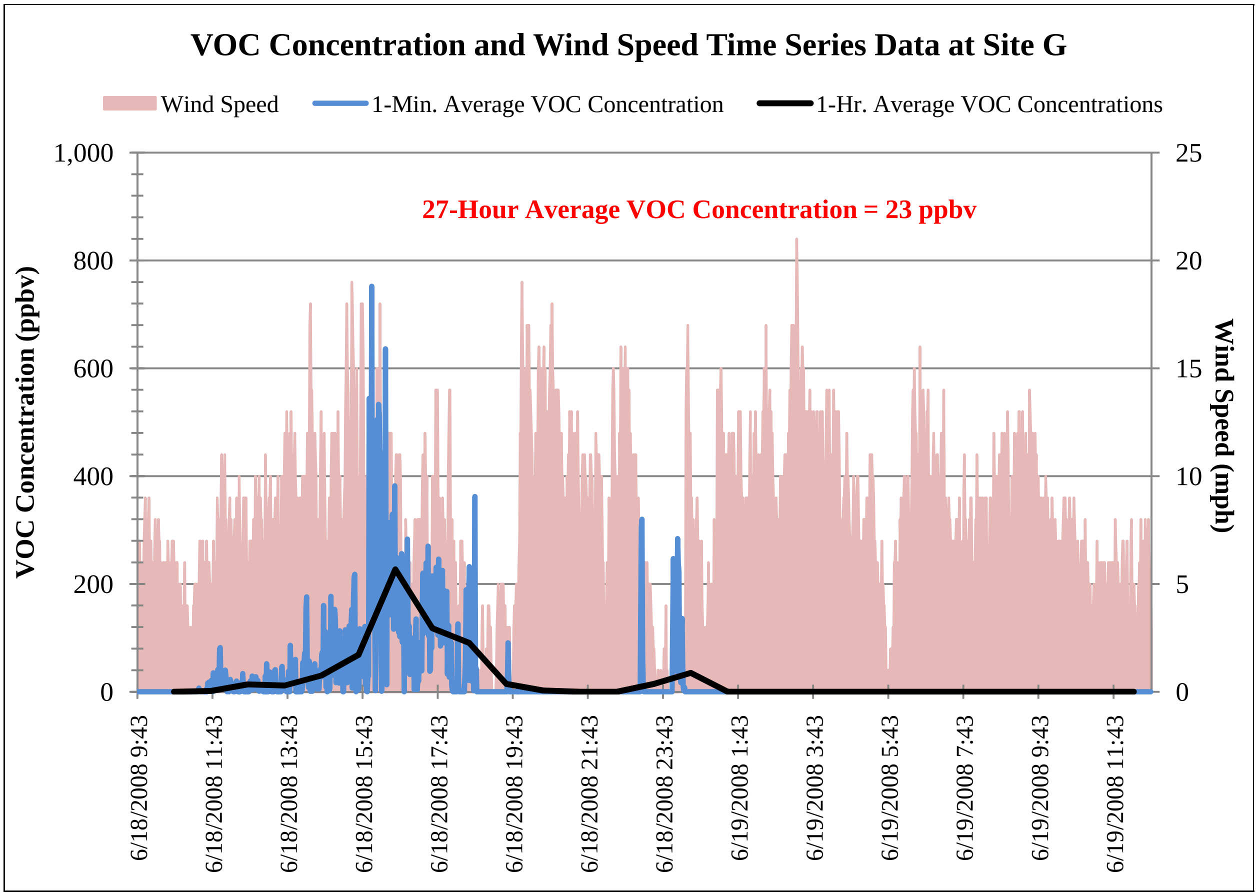


Figure 64. Time Series Data for VOC Concentration and Wind Speed at Site G

Table 35. Maximum and Average VOC Concentrations

Maximum VOC Concentration (taken from 1 minute avgs.)	Average VOC Concentration (averaged over 27 hours)
752 ppbv	23 ppbv

Figure 64 shows that for the small amount of time the wind was blowing and a VOC concentration was detected, a high of over 750 ppbv was recorded. This took place at approximately 16:00 on 6/18/2008. According to an activity log from the site, from 13:15 to midnight on 6/18/2008 there were wells flowing back into the open topped tanks. In addition, there were water trucks running around the clock filling tanks. This site saw an average wind speed of 7.6 mph, and an VOC average concentration of 23 ppbv. The wind was out of the WSW, as measured by the met station at the eastern monitoring site. It is likely that the VOC concentrations that were picked up were from the tanks located approximately to the southwest of the eastern monitor, since the concentrations are associated with the WSW wind.

The NMOC monitors were all run for time periods of 25 hours each. The SNMOC, unknown and TNMOC well pad average concentrations were 1,182, 181 and 1,367 ppbC, respectively. The unknowns comprised 20% of the total NMOC concentration on average. The background site concentrations were 230, 52 and 282 ppbC, respectively, with an unknown percentage of 18%. The SNMOC and TNMOC concentrations for this site are larger than those from the 2006 Front Range study. The unknown concentrations, however, were lower for this site (18%) than the Front Range (58%). The background site recorded the lowest average TNMOC concentration (282 ppbC) and the southern site recorded the largest (4,560 ppbC). The southern site recorded concentrations that were at least five times higher than any other monitoring site. The southern site also had the lowest percentage of unknowns, at a value of 9%. The production tanks were near the eastern monitors, so the primarily northeasterly winds would have pushed the pollutants toward the southern monitor. The SNMOC, unknown and TNMOC concentration graph can be seen in Figure 65.

As previously mentioned, the southern site had the highest SNMOC and TNMOC concentration values. The interesting thing to note here is that ethane and propane were not the highest concentrations. In fact, they are not even on the list of estimated concentrations. Of the 58 detected compounds, ethane, propane and toluene had concentrations greater than 5 ppbv at 26, 9 and 8 ppbv, respectively. The unknowns made up 9% of the total NMOC concentration. There were 13 non-detected/non-reported compounds. All remaining compounds had estimated concentrations that can be seen in Figure 66. This is the first time that the xylene and n-pentane concentrations were that high. Isobutene/1-butene co-eluted with another compound.

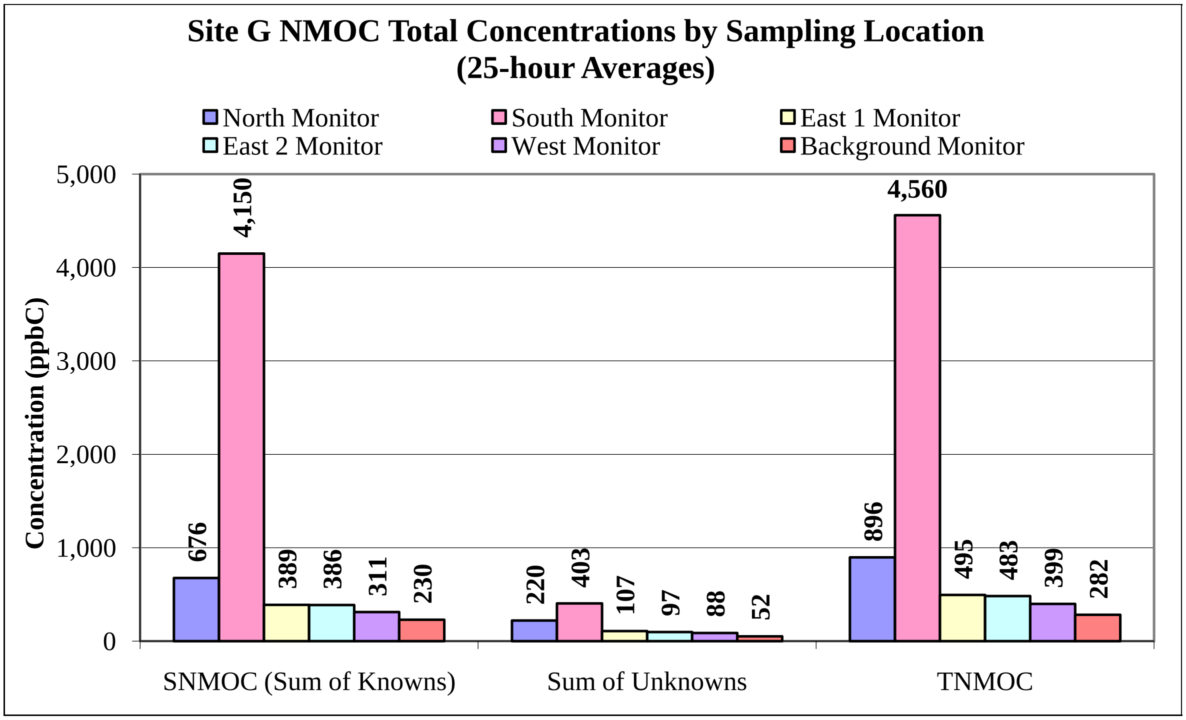


Figure 65. Site G NMOC Total Concentrations by Sampling Location

Table 36. Well Pad Avg. and Background Monitor Concentrations and RPDs

	Well Pad Avg. Concentration (25-hr. avg.) ppbC	**Background Monitor Concentration (25 hr. avg.) ppbC**	**RPD %**
SNMOC	1,182	230	135
Sum of Unknowns	193	52	115
TNMOC	1,367	282	132

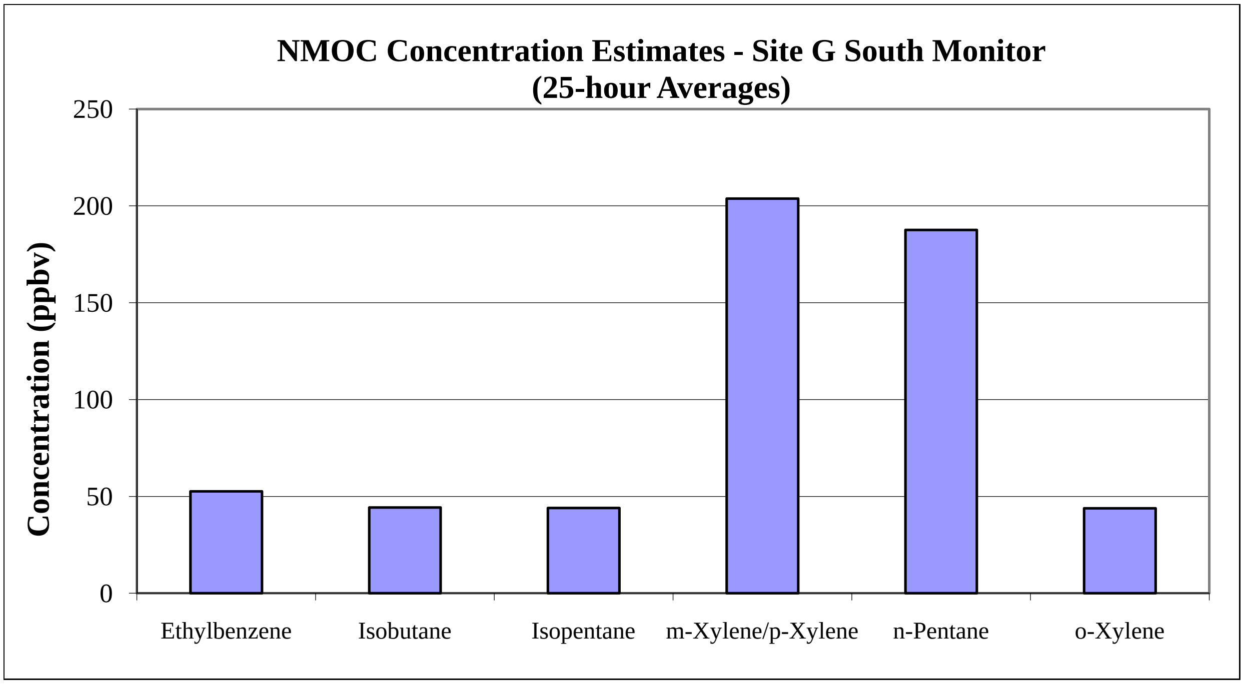


Figure 66. NMOC Concentration Estimates at Site G South

The northern site recorded the second highest NMOC values with concentrations of SNMOC and TNMOC of 676 and 896 ppbC, respectively. The ethane concentration was an estimate at 153 ppbv, and isobutene/1-butene co-eluted with another compound. Of the remaining compounds, 20 were non-detected/non-reported and 56 had detectable concentrations. Of the detectable, propane was highest with an approximate 25 ppbv concentration. All others were less than 5ppbv. As was previously stated, the unknowns were 25% of the total NMOC concentration.

The co-located monitors at the eastern site both had only ethane as an estimated concentration, at 65 ppbv for both sites. The primary site had 19 non-detectable/non-reportable compounds, as did the secondary site. Both also had 58 detectable compounds, of which propane showed the highest values of 15 at both sites. All other concentrations were less than 4 ppbv. Both samplers had remarkably similar concentrations with few difference, including the SNMOC and TNMOC concentrations of just under 400 ppbC and 500 ppbC, respectively.

Table 37. Duplicate NMOC Sample Results and RPDs

ANALYTE	RESULT 1 (ppbC)	RESULT 2 (ppbC)	RPD (%)
1,2,3-Trimethylbenzene	1.74	1.78	2
1,2,4-Trimethylbenzene	3.57	3.57	0
1,3,5-Trimethylbenzene	1.94	2.12	9
1,3-Butadiene	0.183	0.173	6
1-Dodecene	1.9	0.171	167
1-Heptene	1.49	1.65	10
1-Hexene	0.191	0.195	2
1-Nonene	0.451	0.414	9
1-Pentene	0.219	0.257	16
1-Undecene	0.195	0.227	15
2,2,3-Trimethylpentane	0.524	0.513	2
2,2-Dimethylbutane	0.773	0.838	8
2,3,4-Trimethylpentane	0.115	0.159	32
2,3-Dimethylbutane	1.36	1.39	2

ANALYTE	RESULT 1 (ppbC)	RESULT 2 (ppbC)	RPD (%)
2,3-Dimethylpentane	0.927	1	8
2,4-Dimethylpentane	0.631	0.685	8
2-Methyl-2-butene	0.233	0.219	6
2-Methylheptane	2.75	2.81	2
2-Methylhexane	3.34	3.31	1
2-Methylpentane	6.05	6.95	14
3-Methylheptane	1.93	2.11	9
3-Methylhexane	2.75	2.97	8
3-Methylpentane	3.76	4.09	8
4-Methyl-1-pentene	0.825	0.398	70
Acetylene	0.819	0.815	0
a-Pinene	1.09	1.19	9
Benzene	2.7	2.84	5
cis-2-Butene	0.079	0.131	50
cis-2-Hexene	0.486	0.476	2
cis-2-Pentene	0.078	0.094	19
Cyclohexane	5.37	5.69	6
Cyclopentane	0.713	0.67	6
Cyclopentene	0.332	0.5	40
Ethane	132	130	2
Ethylbenzene	0.888	0.894	1
Ethylene	2.47	2.4	3
Isobutane	14.1	13.9	1
Isobutene/1-Butene	9.84	14.1	36
Isopentane	17.6	19.7	11
Isoprene	0.941	0.978	4
Isopropylbenzene	0.267	0.141	62
m-Diethylbenzene	0.464	0.585	23
Methylcyclohexane	15	16	6
Methylcyclopentane	4.25	4.63	9
m-Ethyltoluene	1.32	1.44	9
m-Xylene/p-Xylene	9.29	9.66	4
n-Butane	14.6	14.4	1
n-Decane	6.08	6.61	8
n-Dodecane	3.66	3.21	13
n-Heptane	6.26	6.59	5
n-Hexane	7.44	8.45	13
n-Nonane	6.82	6.84	0
n-Octane	8.72	8.45	3
n-Pentane	8.91	8.91	0
n-Propylbenzene	0.515	0.558	8
n-Tridecane	1.2	1.03	15
n-Undecane	5.31	5.5	4
o-Ethyltoluene	1.21	1.2	1
o-Xylene	1.57	1.59	1
p-Diethylbenzene	0.631	0.91	36
p-Ethyltoluene	1.19	1.06	12

ANALYTE	RESULT 1 (ppbC)	RESULT 2 (ppbC)	RPD (%)
Propane	44.9	44.3	1
Propylene	0.976	0.954	2
SNMOC (Sum of Knowns)	386	395	2
Sum of Unknowns	104	103	1
TNMOC	490	498	2
Toluene	8.25	8.54	3
trans-2-Butene	0.167	0.205	20
trans-2-Pentene	0.151	0.189	22

As with the eastern sites, the western site also had ethane as an estimated concentration at 61 ppbv. In addition to the estimate, this site also had an unknown compound co-elute with the isobutene/1-butene. Of the remaining 76 compounds, 23 were non-detectable/non-reportable and 53 were detected. Of those 53, propane was the highest concentration at just over 14 ppbv. All others were less than 4 ppbv. The SNMOC, unknown and TNMOC concentrations were 311, 88 and 399 ppbC, respectively.

The background site recorded the lowest concentrations. There were no estimates and the non reported compounds due to co-elution of an unknown was 4methyl-1-pentene, not the normal isobutene/1-butene seen previously. As usual, the highest concentrations of the 50 detected compounds were ethane at 30 ppbv and propane at 13 ppbv. All others were less than 5 ppbv.

In summary, the average of the particulate concentrations recorded around the well pad (16.7 μg/m^3) was much lower than the EPA's recommended 24 hour maximum exposure value (35 μg/m^3), and appears to be non-uniform for this site when compared to the value obtained by the background monitor (7.1 μg/m^3) and the relative percent difference of 81% between the values. The duplicate samples taken show some agreement with a relative percent difference of 11% between the samplers. The 27-hour average VOC concentration of 23 ppbv that was observed appears to be highly dependent on the local meteorological conditions around the site, meaning that if the wind was not blowing in a direction that pushed the VOC plume toward the monitor concentrations were not recorded. The one-minute maximum VOC concentration observed was 752 ppbv. The primary wind direction at this site was from the northeast, with an average speed of 7.6 mph. The NMOC concentrations also seem to be non-uniform for this site, as the average of the concentrations around the well pad is not similar to the values recorded by the background monitor. The well pad averages for SNMOCs, unknowns and TNMOCs were 1,182, 193, and 1,367 ppbC, respectively, while the background monitor concentrations were 230, 52 and 282 ppbC, respectively. This gives an average relative percent difference of 127% between the background and well pad monitors. The duplicate NMOC samples showed good agreement with an average relative percent difference of 4% between the samplers.

5.2.5 COMPLETION SUMMARY

The average particulate concentrations recorded were highest at Site G, with an average of 16.7 micrograms per cubic meter. Site A recorded the second highest average particulate concentration at 10.1 μg/m^3, with sites C and E recording values of 7.9 and 7.3 μg/m^3. At sites E and G the southern monitors recorded the highest values of 10.5 and 20.5 μg/m^3. At sites A and C the eastern monitors recorded the highest values of 13.0 and 9.2 μg/m^3, respectively. The average concentration values are shown in Figure 67.

All of the particulate samplers in operation around the completion sites were run for 24 hours, with the exceptions of the background sampler at Site G (23 hours), and the background, east 2, north and south samplers at Site E (17, 19, 19, and 18 hours, respectively). At this time it is unclear why the samplers were run for different times at those sites.

Although the background sampler was run for one hour less at Site G, the concentration value obtained does appear to be in line with those obtained from at Sites A, C and E. The lower background value at Site E is likely due to the fact that the sampler there was run for 7 hours less than the other background samplers. The background sampler at Site A recorded a value that is identical to the average concentration obtained for the well pad. The background samplers at Sites C and E also recorded values that were similar to the average particulate concentrations obtained over the well pads for those sites. The average well pad particulate concentration at Site G, however, was more than twice that of the background monitor for that site. The larger particulate concentration is likely due to the increased average wind speed at that site.

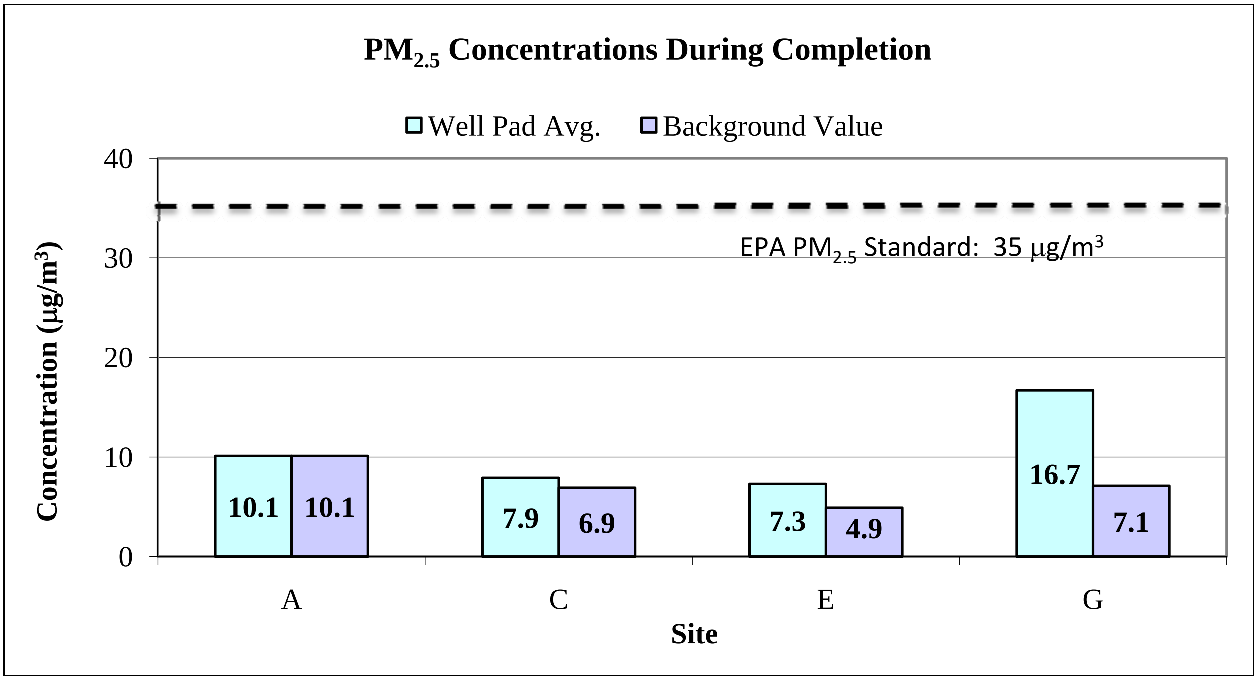


Figure 67. Average Completion Concentrations – $PM_{2.5}$

Table 38. Well Pad Avg. and Background Monitor $PM_{2.5}$ Concentrations and RPDs

Site	Well Pad Avg. Conc. (µg/m^3)	Background Monitor Conc. (µg/m^3)	RPD (%)
A	10.1	10.1	0
C	7.9	6.9	14
E	7.3	4.9	39
G	16.7	7.1	81

Table 39. Collocated Particulate Sampler Concentrations and RPDs

Site	Result 1 (µg/m^3)	Result 2 (µg/m^3)	RPD (%)
A	N/A	N/A	N/A
C	7.8	7.5	4
E	6.8	7.0	3
G	16.9	15.1	11

Sites A and E had primary wind directions from the west to southwest, with smaller percentages of wind coming from each of the other directions, and also had the lowest RPD values at 0 and 3%, respectively. Sites C and G saw winds primarily from an easterly direction. Site G also recorded winds from a southwesterly direction. The highest average wind speed recorded was at Site G, with an average of 7.6 mph. Site A was second with a value of 5 mph. Site E was third (4.1 mph) and Site C was last (2.7 mph).

There were very large spikes of VOC concentrations seen at the completion sites. The highest spike was recorded at Site A with a value of approximately 25,000 ppbv. The second highest spike was seen at Site C, with a value approaching 5,500 ppbv. Site G was third with its VOC spike value of near 750 ppbv. Site E recorded a concentration spike of around 70 ppbv. Site A also had the highest VOC average concentration at 3,023 ppbv over 13 hours. Sites C, G and E were second, third and last with values of 126, 23 and 9 ppbv, respectively, over 27 hours.

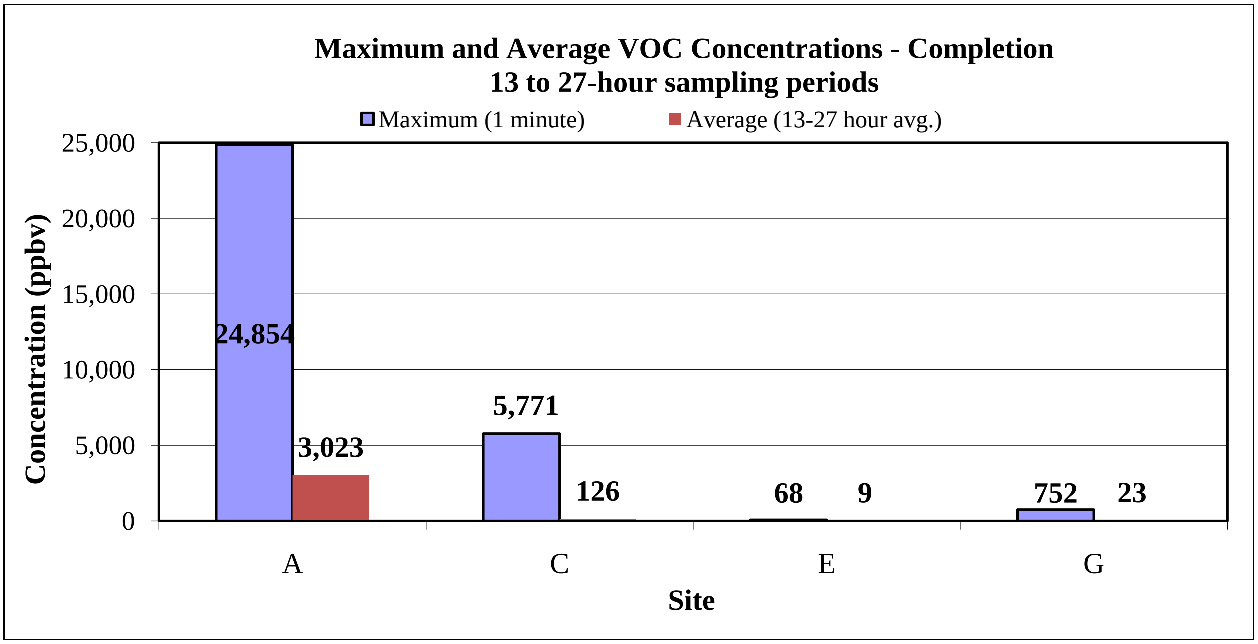


Figure 68. Average Completion Concentrations - VOCs

Although all of the NMOC samplers were not run for the same amount of time, their run times were within 3 hours of each other, ranging from 24 to 27 hour sampling periods. As such, the concentrations obtained are assumed to be similar enough for comparison purposes in this report. Site A recorded the highest SNMOC average value at 8,761 ppbC. Site C was second with 3,000 ppbC. Site G was third with 1,182 ppbC, and Site E was last with 416 ppbC. The highest average TNMOC concentration was also seen at Site A, with Sites C, G and E rounding out the second, third and fourth place spots with values of 9,790, 5,390, 1,367 and 501 ppbC, respectively. The unknown percentages ranged between 9 and 19%. These data are shown in Figure 69 and Figure 70.

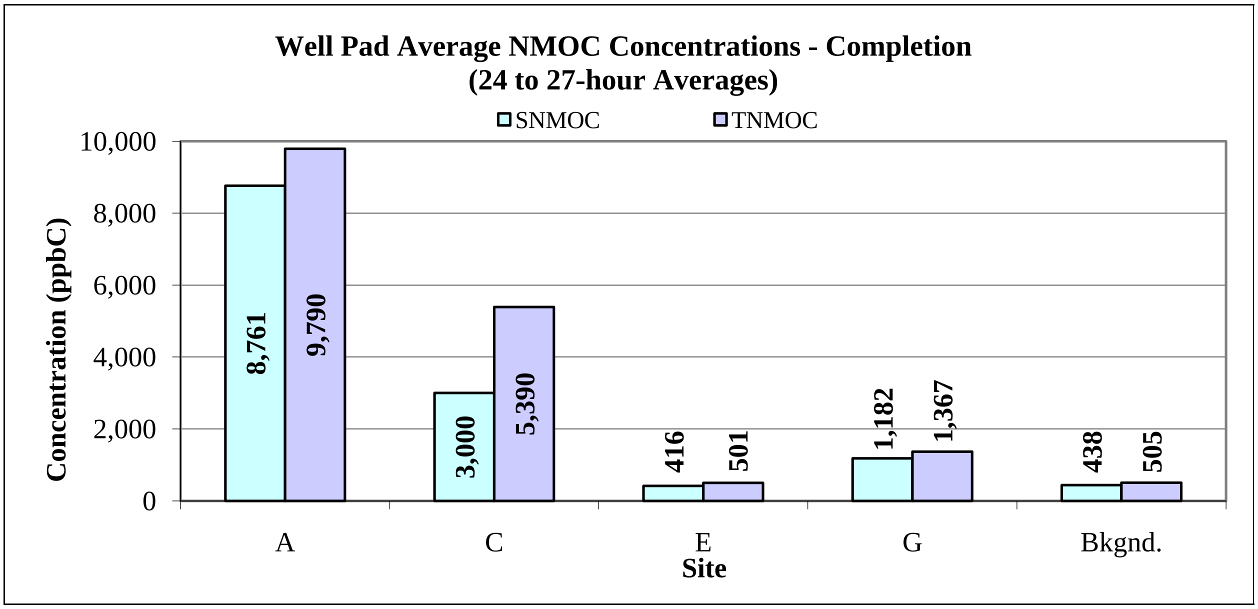


Figure 69. Average Well Pad Completion Concentrations – TNMOC and SNMOC

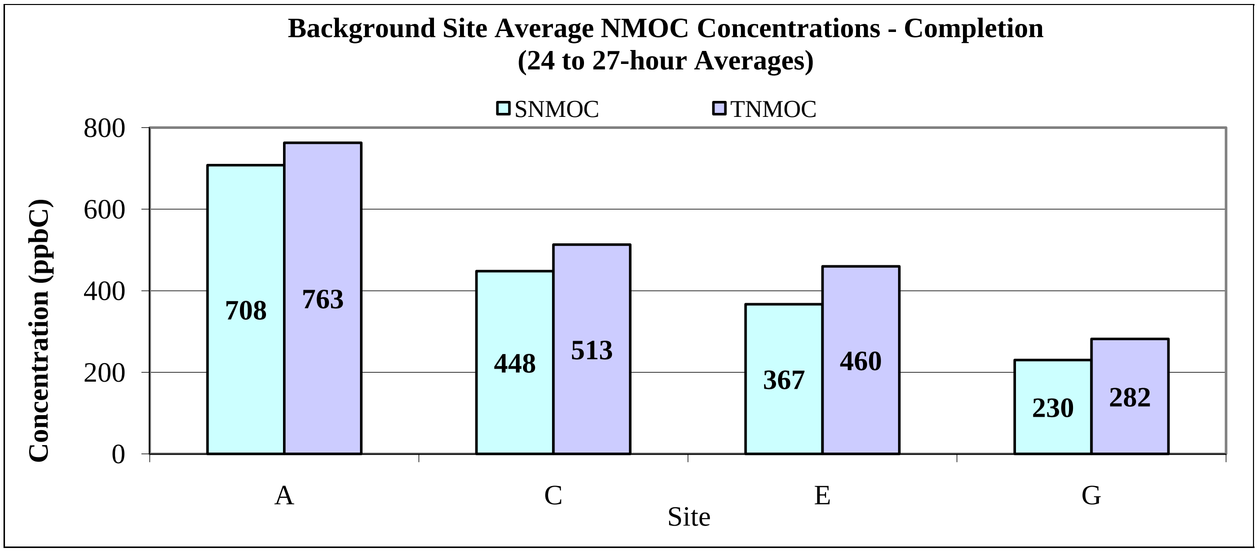


Figure 70. Average Background Site Completion Concentrations – TNMOC and SNMOC

At Site A there were 9 commonly non detected NMOC compounds found at all the sampling locations, including the background site. At Site C there were 15, Site E there were 19 and at Site G there were 9. Of these compounds, only three were non-detects at all of the completion sampling sites. They were 2-methyl-1-pentene, propyne and trans-2-hexene. All of the compounds that were non-detects at each of the monitoring locations on each site are listed in Table 40. The compounds highlighted in yellow are the three that were non-detects at all of the completion sampling sites. There were 15 compounds that were non-detects at two or more of the sites. There were only three compounds that were non-detects at only one site. These compounds were 1-Nonene, 1-Octene, and Isopropylbenzene, and the site was Site E.

Table 40. Common Non-Detected NMOC Compounds from all Completion Sites

Site A	Site C	Site E	Site G
1,3-Butadiene		1,3-Butadiene	
1-Decene	1-Decene	1-Decene	
1-Hexene	1-Hexene	1-Hexene	
		1-Nonene	
		1-Octene	
	1-Tridecene	1-Tridecene	1-Tridecene
2,2,4-Trimethylpentane	2,2,4-Trimethylpentane	2,2,4-Trimethylpentane	
2-Ethyl-1-butene	2-Ethyl-1-butene		2-Ethyl-1-butene
	2-Methyl-1-butene		2-Methyl-1-butene
2-Methyl-1-pentene	2-Methyl-1-pentene	2-Methyl-1-pentene	2-Methyl-1-pentene
	2-Methyl-2-butene	2-Methyl-2-butene	
	3-Methyl-1-butene	3-Methyl-1-butene	3-Methyl-1-butene
	4-Methyl-1-pentene	4-Methyl-1-pentene	
		cis-2-Butene	cis-2-Butene
cis-2-Hexene		cis-2-Hexene	
	cis-2-Pentene	cis-2-Pentene	cis-2-Pentene
		Isopropylbenzene	
Propyne	Propyne	Propyne	Propyne
	Styrene	Styrene	
trans-2-Hexene	trans-2-Hexene	trans-2-Hexene	trans-2-Hexene
	trans-2-Pentene	trans-2-Pentene	

Table 41 lists the 45 compounds that were detected in greater than 90% of the samples taken from the completion sites. The compounds are placed in order from the highest ozone forming potential to the lowest ozone forming potential. Twenty-four of the compounds listed have MIR values over 10, where only one compound from the drilling sites had a value over 10—isopentane. Large ozone reactivities indicate the potential for the formation of large quantities of ozone.

Table 41. Compounds Detected in >90% of Samples

Analyte	MIR	Completion Avg. (ppbC)	O_3 Reactiv. MIR*avg.
m-Xylene/p-Xylene	2.05	148.5	304.9
Propane	0.17	636.9	109.2
Isobutane	0.41	244.4	99.1
n-Butane	0.40	222.7	89.0
Isopentane	0.50	173.6	87.1
n-Pentane	0.46	156.9	72.2
Methylcyclohexane	0.58	121.9	70.2
Toluene	1.09	58.7	63.9
Ethane	0.10	602.8	58.5
o-Xylene	2.07	28.1	58.1
1,3,5-Trimethylbenzene	3.12	10.7	33.3
2-Methylpentane	0.53	49.1	26.2
n-Hexane	0.43	57.2	24.5
1,2,4-Trimethylbenzene	2.00	12.2	24.3
Ethylbenzene	0.77	27.2	21.0
n-Heptane	0.38	53.2	20.0
n-Octane	0.32	60.7	19.7
Methylcyclopentane	0.70	27.9	19.6
m-Ethyltoluene	2.61	6.7	17.6
Cyclohexane	0.42	41.0	17.3
3-Methylpentane	0.62	27.7	17.1
1-Heptene	1.23	11.1	13.6
3-Methylhexane	0.55	20.7	11.4
n-Nonane	0.28	40.0	11.0
2-Methylhexane	0.41	21.9	8.9
o-Ethyltoluene	1.84	4.6	8.5
2-Methylheptane	0.35	22.3	7.8
n-Decane	0.24	28.2	6.8
a-Pinene	1.22	4.8	5.8
3-Methylheptane	0.40	14.4	5.7
p-Ethyltoluene	1.04	5.2	5.4
Ethylene	2.65	2.0	5.2
Cyclopentane	0.78	6.1	4.8
n-Undecane	0.21	20.6	4.4
2,3-Dimethylbutane	0.34	13.0	4.4
Benzene	0.22	14.9	3.3
2,3-Dimethylpentane	0.46	6.7	3.1
2,2-Dimethylbutane	0.40	7.2	2.9
Propylene	3.38	0.8	2.9

Analyte	MIR	Completion Avg. (ppbC)	O_3 Reactiv. MIR*avg.
Isoprene	3.03	0.9	2.8
n-Dodecane	0.19	11.8	2.2
2,4-Dimethylpentane	0.49	4.4	2.2
Cyclopentene	2.08	0.4	0.9
1-Pentene	2.26	0.2	0.5
Acetylene	0.34	0.7	0.2

In summary, the particulate values appear to be indicative of overall background values for the areas, and are much lower than the EPA standard, with the exception of Site G, which was higher. Site E did not have all the samplers operating for the same amount of time. There was an average RPD of 34% between the well pad averages and the background values, and an average RPD of 6% between the collocated samplers. The meteorological parameters appear to be highly dependent on the topography surrounding each well pad, showing varied speeds and directions. The VOC samplers were not all run for the same amount of time, varying from 13 to 27 hours, which makes comparing these results difficult at best. The sampling period average VOC concentrations ranged from 9 to 3,023 ppbv. The NMOC samplers were also not run for the same amounts of time, ranging between 24 and 27 hours, but were similar enough that comparisons could be made rather accurately. The data shows that there are significant differences between Sites A, C and G, all of which recorded extremely high NMOC concentrations. Site E, however, did not record concentrations of that nature. This is likely due to the fact that the placement of the monitors in relation to the prevailing wind direction put them in the direct path of any contaminant plumes that were present. The data from Site E would seem to indicate that the values obtained may be indicative of background concentrations in that area. There were only 3 compounds that were not detected at all of the sites, 15 that were not detected at 2 or more sites and 3 that were not detected at only one of the sites. There were 45 of the 78 compounds detected in greater than 90% of the samples.

5.3 DRILLING VS. COMPLETION COMPARISON

5.3.1 $PM_{2.5}$

The majority of the particulate samplers were all in operation for 24 hours. There were only two sites that did not meet this criteria, Site E and Site G, both of which are completion sites. The particulate concentrations observed at both the drilling and completion sites appear to be more indicative of the area wide background concentration, with a few exceptions. The particulate average over all the background sites is 6.9 $\mu g/m^3$, while the average over all the well pad samplers is 9.4 $\mu g/m^3$. The average value for all the drilling sites was 8.3 $\mu g/m^3$, and the average over all of the completion sites was 10.5 $\mu g/m^3$. The average of the drilling background sites was 6.5 $\mu g/m^3$, and for all the completion background sites it was 7.3 $\mu g/m^3$. Table 42 lists the $PM_{2.5}$ concentration averages for all sites, with the highlighted rows indicating the completion sites. There was a difference of 2.5 $\mu g/m^3$ between the averages for all the sites and all the background sites. A 2.3 $\mu g/m^3$ difference is seen between the averages for the drilling sites versus the completion sites, and a 0.8 $\mu g/m^3$ difference was seen between the drilling and completion background sites. The samplers at Site E recorded the lowest concentrations, which is likely due to the fact that all but two of the samplers were run for less than a standard 24 hour period.

Table 42. Average $PM_{2.5}$ Concentrations at all Sites

Site	Average $PM_{2.5}$ Concentration ($\mu g/m^3$) Well Pads	Background Sites
A	10.1	10.1
B	9.3	8.2
C	7.9	6.9
D	7.8	5.5
E	7.3	4.9
F	8.0	5.0
G	16.7	7.1
H	7.9	7.3

The highest particulate value seen was recorded at Site G, a completion site. This could be due to more diesel smoke sources being used during the completion process, but without knowledge of the equipment being used at the site it is difficult to say that with any certainty. The second highest value recorded was from Site A, another completion site. It appears that there are more fine particulates associated with the completion phase than with the actual drilling phase, which seems somewhat counterintuitive. However, when considering that some of the VOCs and NMOCs can react very quickly in the presence of sunlight to form various small particles, in addition to ozone, it makes sense. The completion sites saw higher organic compound concentrations than the drilling sites did and this larger volume of compounds would provide an increased number of opportunities for volatile compounds to react quickly and form fine particulate matter.

Although the particulate concentrations were slightly higher at the completion sites as opposed to the drilling sites, it should be noted that the concentration values obtained for both types of sites were well below the 24-hour averaged EPA standard of 35 $\mu g/m^3$.

5.3.2 VOCs

The average VOC concentrations seen at the completion sites were much larger than the average concentrations seen at the drilling sites. Table 43 lists the average VOC concentrations found at all sites. The highlighted rows indicate the sites that were undergoing completion processes, while the non-highlighted rows indicate those undergoing the drilling process. The average of the completion site concentrations was 795 ppbv, while that at the drilling sites was 58 ppbv, a more than ten-fold difference. The average wind speeds seen at the completion sites was 4.9 mph, while that at the drilling sites was 3.3 mph. Site A recorded the highest average VOC concentration of all the sites. The data from this site indicates that the wind conditions were such that the wind pushed the plume of pollutants right toward the VOC monitor at this site. The second highest average VOC concentration was found at drilling Site H. This site recorded an average of 166 ppbv, which is roughly 5 times larger than the next closest drilling concentration. There were several concentration spikes to over 600 ppbv, with one spike to over 1,100 ppbv.

Table 43. Average VOC Concentrations and Wind Speeds at All Sites

Site	Average VOC Concentration (ppbv)	Average Wind Speed (mph)
A	3,023	5.0
B	25	1.8
C	126	2.7
D	34	5.4
E	9	4.1
F	6	2.4
G	23	7.6
H	166	3.6

The lowest completion concentration recorded was an average of 9.3 ppbv at Site E, and the lowest drilling concentration recorded was 6.0 ppbv at Site F. Though these sites had lower average wind speeds than Sites A, D and G, they recorded lower average concentrations than Sites A, D and G did. This seems somewhat out of the ordinary, as the majority of the data seen indicated that increased wind speeds meant decreased VOC concentrations.

5.3.3 NMOCs

The NMOC sampling periods ranged from 24 to 27 hours between the drilling and completion sites. As such, the concentrations obtained are assumed to be similar enough for comparison purposes in this report. Table 44 lists the average concentrations for SNMOC, unknown and TNMOC compounds. As with the previous two sections, the highlighted rows indicate the sites undergoing the completion process. Once again, completion site A had the highest average SNMOC, unknown and TNMOC concentrations with values of 8,761, 1,025 and 9,790 ppbC. The second and third highest averages were also from completion sites, Sites C and G. A drilling site, however, had the fourth highest average at 524 ppbC versus that of the lowest completion site (Site E) at 416 ppbC. The average SNMOC, unknown and TNMOC concentrations for all the completion sites were 3,340, 371 and 4,262 ppbC. The averages for the drilling sites were 349, 101 and 452 ppbC, respectively. The differences in SNMOC and TNMOC average concentrations are nearly ten-fold. The background site SNMOC, unknown and TNMOC average concentrations at the completion sites were 438, 67 and 505 ppbC. Those same concentrations for the drilling background sites were 352, 72 and 422 ppbC. The completion background site concentrations were slightly higher on average than those seen at the drilling sites, with the exception of the unknown concentration, which was higher at the drilling sites. In addition, the completion sites had 24 compounds that were detected in greater than 90% of the samples taken with MIR values above 10, where there was only one compound that met the same criteria from the drilling sites—isopentane.

Table 44. Average SNMOC, Unknown and TNMOC Concentrations for All Sites

Site	Average SNMOC Concentration (ppbC)		Average Unknown Concentration (ppbC)		Average TNMOC Concentration (ppbC)	
	Well Pads	Background Sites	Well Pads	Background Sites	Well Pads	Background Sites
A	8,761	708	1,025	55	9,790	763
B	247	257	118	73	364	324
C	3,000	448	191	66	5,390	513
D	524	552	138	115	663	667
E	416	367	84	93	501	460
F	273	210	63	45	336	255
G	1,182	230	183	52	1,367	282
H	355	387	84	55	443	443

It is worth noting here that completion Sites A and C also had the highest average VOC concentrations recorded, and the second and fourth highest fine particulate concentrations recorded. There is a definite pattern of much higher organic compound concentrations at the completion sites as opposed to the drilling sites. During the completion process, the oil/natural gas products were routed to an open top tank to before shutting the well in. This serves two purposes: (1) when initially tapped, the natural gas products are under extremely high pressures and are difficult to capture until the pressures drop down to certain levels, and (2) non-salable product is vented off. Once the pressures have dropped and the non-salable product has passed, the flow is re-routed from the open top tanks to a regular storage vessel to be pumped and shipped out. This venting is the source of large amounts of organic chemicals in the air on a daily basis at all the different wells sites using this type of completion process. These compounds may be associated with odor problems in the areas surrounding the well pad.

6.0 SUMMARY AND CONCLUSIONS

This study was performed at eight different well pad sites throughout Garfield County. Four of the sites were undergoing drilling activities and the other four were undergoing completion activities. The data collected at each of these sites indicates that the completion activities have the potential to pump a very large amount of organic compounds into the surrounding area, and provides support for the push to convert all well completions over to green completion technology in Colorado and elsewhere. The addition of this technology could help reduce future emissions.

Although the sites being monitored are industrial sites that the general public does not have open access to, the large concentrations are of great concern, as many of the well pads are located quite close to populated areas in the County. The continuous long term releases of these types of compounds, combined with the fact that at any given time in the County there are a large number of wells undergoing either the drilling or completion processes, provide the potential for emissions issues in the immediate areas surrounding these sites.

The actual areas affected appear to be quite dependant on the local wind speeds, directions and surrounding topography. Further research into exactly how much the concentrations are affected by each of those items should be pursued in order to fully understand the localized effects that such drilling and completion activities could possibly have on the public at large. Placing VOC monitors and meteorological equipment at all of the monitor locations around the pads, as well as at the background site would be most beneficial to determining where and how far the compounds are transported. Placement of monitors at various distances from the well pads in the primary wind direction would also help provide a clearer picture of the transport issue.

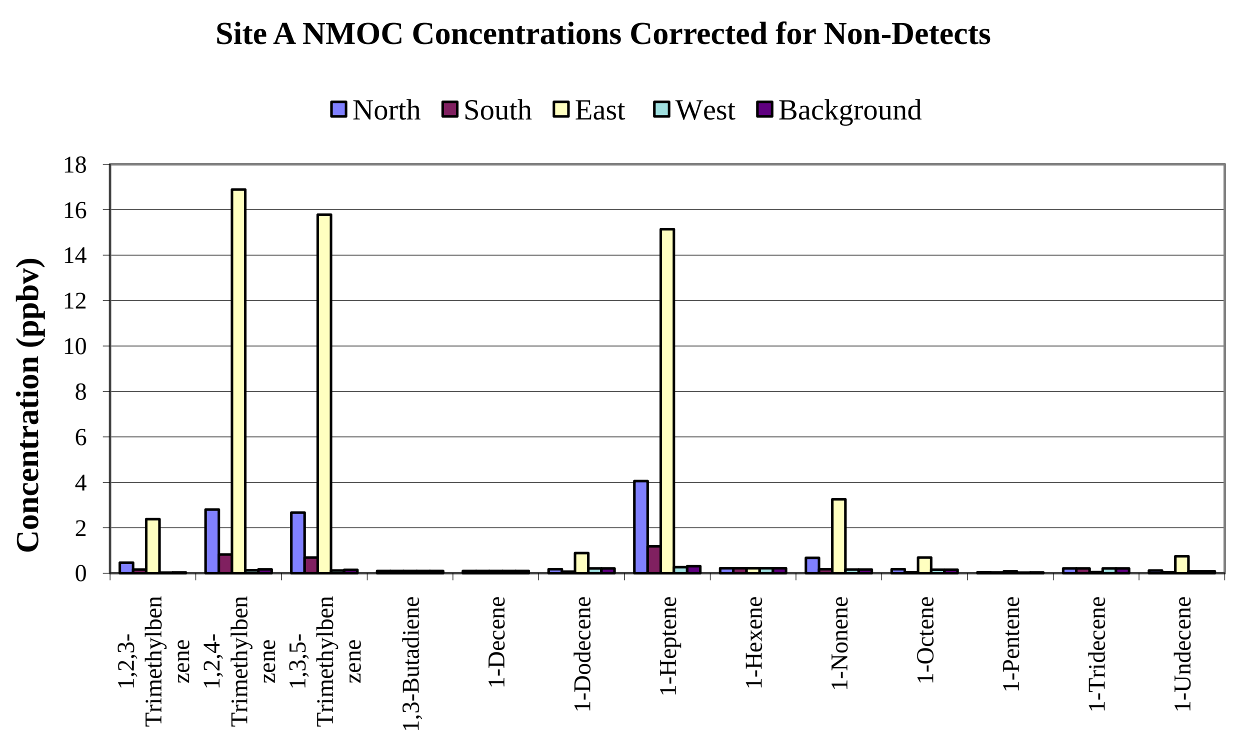
In future research endeavors, it would also be wise to ensure that all the samplers are run for the same amounts of time so that conclusions regarding the data obtained can be more easily made. The addition of sampling around well pads that are undergoing activities other than drilling and completion could also be useful.

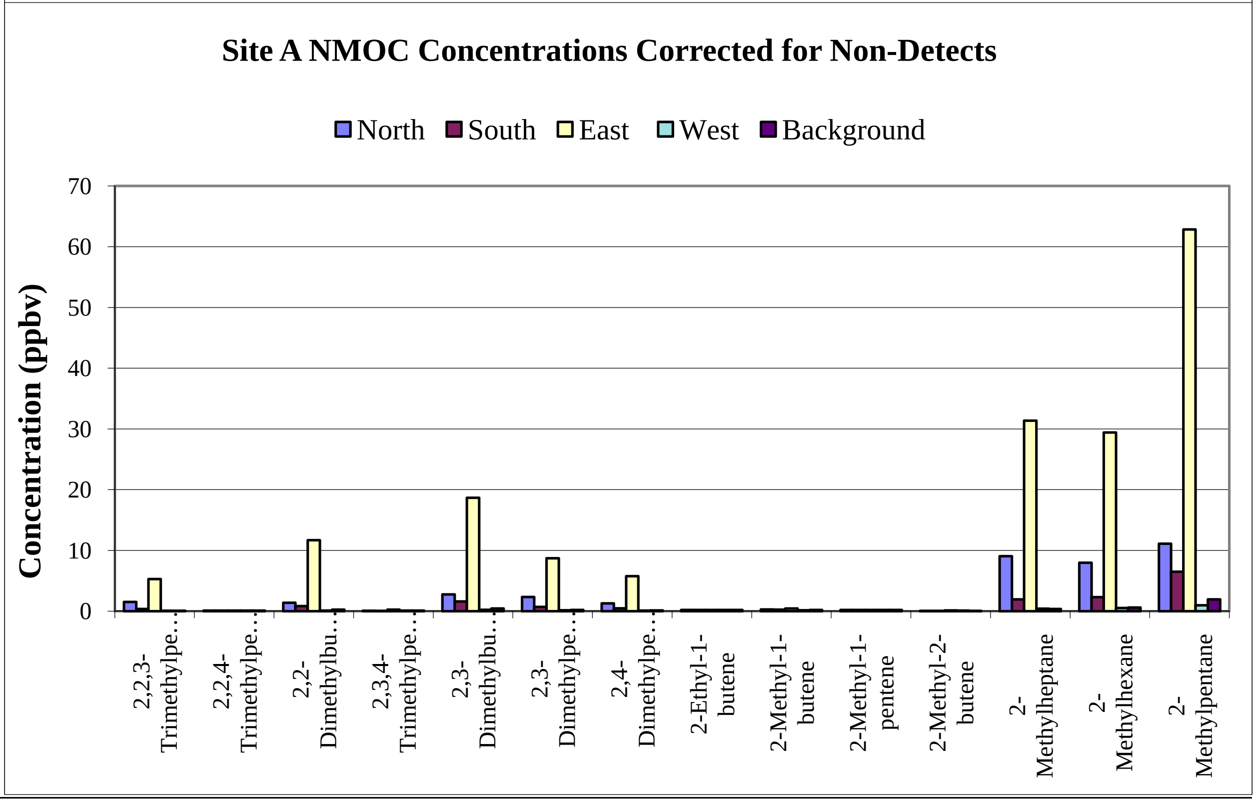
APPENDIX A – SITE A NMOC DATA AND GRAPHS

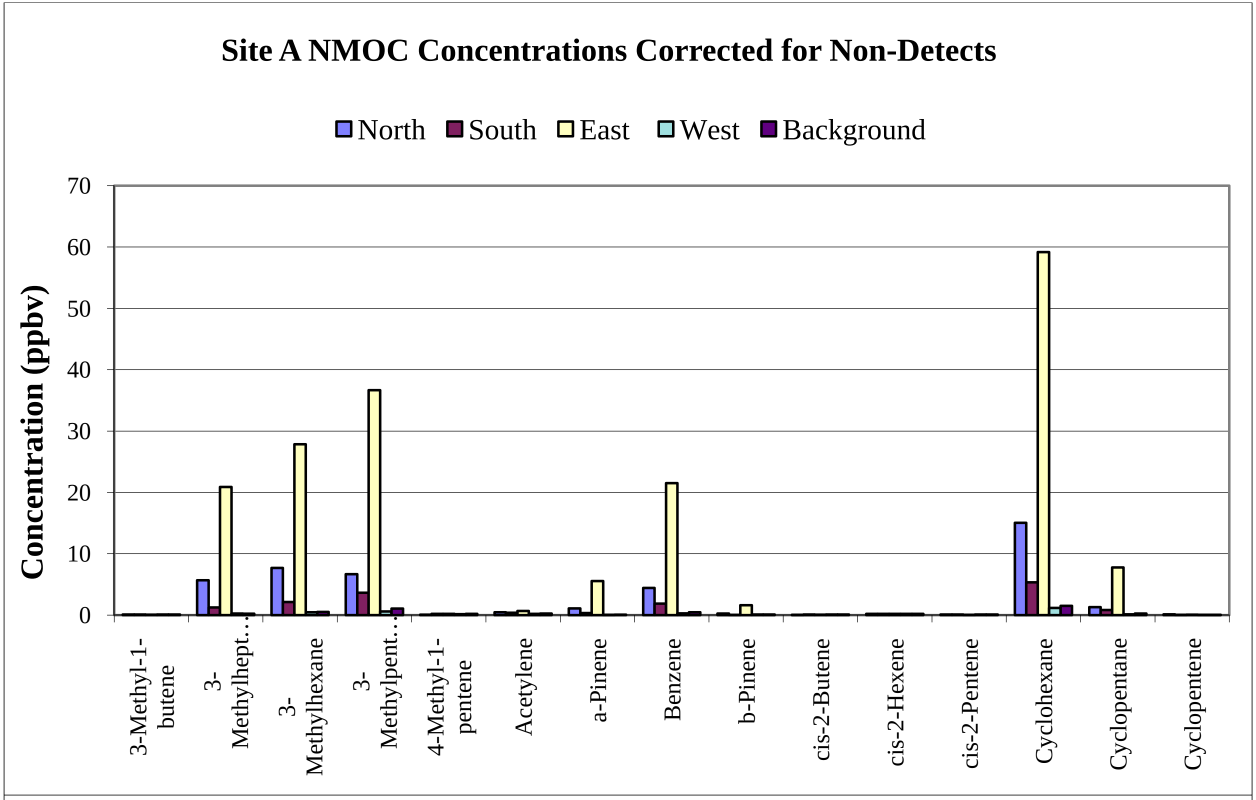
***NOTE – All table and graph values represent 24 to 27 hour sampling periods.**

Analyte	Results					DL	Units
	North	**South**	**East**	**West**	**Background**		
1,2,3-Trimethylbenzene	0.460	0.158	2.378	0.026	0.035	0.024	ppbv
1,2,4-Trimethylbenzene	2.800	0.824	16.889	0.126	0.168	0.027	ppbv
1,3,5-Trimethylbenzene	2.667	0.687	15.778	0.117	0.149	0.022	ppbv
1,3-Butadiene	0.095	0.095	0.095	0.095	0.095	0.048	ppbv
1-Decene	0.100	0.100	0.100	0.100	0.100	0.020	ppbv
1-Dodecene	0.175	0.072	0.883	0.210	0.210	0.035	ppbv
1-Heptene	4.057	1.180	15.143	0.266	0.306	0.056	ppbv
1-Hexene	0.215	0.215	0.215	0.215	0.215	0.072	ppbv
1-Nonene	0.673	0.177	3.256	0.160	0.160	0.036	ppbv
1-Octene	0.174	0.042	0.689	0.155	0.155	0.039	ppbv
1-Pentene	0.039	0.037	0.085	0.026	0.032	0.024	ppbv
1-Tridecene	0.210	0.210	0.049	0.210	0.210	0.032	ppbv
1-Undecene	0.116	0.042	0.748	0.085	0.085	0.015	ppbv
2,2,3-Trimethylpentane	1.525	0.351	5.300	0.071	0.061	0.039	ppbv
2,2,4-Trimethylpentane	0.110	0.110	0.110	0.110	0.110	0.028	ppbv
2,2-Dimethylbutane	1.380	0.847	11.700	0.107	0.245	0.023	ppbv
2,3,4-Trimethylpentane	0.084	0.043	0.259	0.090	0.090	0.023	ppbv
2,3-Dimethylbutane	2.750	1.598	18.667	0.222	0.453	0.033	ppbv
2,3-Dimethylpentane	2.343	0.699	8.700	0.164	0.193	0.056	ppbv
2,4-Dimethylpentane	1.291	0.469	5.757	0.094	0.127	0.034	ppbv
2-Ethyl-1-butene	0.215	0.215	0.215	0.215	0.215	0.072	ppbv
2-Methyl-1-butene	0.292	0.266	0.440	0.154	0.206	0.040	ppbv
2-Methyl-1-pentene	0.215	0.215	0.215	0.215	0.215	0.072	ppbv
2-Methyl-2-butene	0.057	0.044	0.135	0.100	0.041	0.040	ppbv
2-Methylheptane	9.050	1.938	31.375	0.414	0.364	0.023	ppbv
2-Methylhexane	7.971	2.300	29.429	0.524	0.597	0.026	ppbv
2-Methylpentane	11.100	6.500	62.833	0.970	1.950	0.013	ppbv
3-Methyl-1-butene	0.100	0.100	0.087	0.100	0.100	0.040	ppbv
3-Methylheptane	5.688	1.263	20.875	0.271	0.238	0.025	ppbv
3-Methylhexane	7.686	2.129	27.857	0.469	0.514	0.033	ppbv
3-Methylpentane	6.683	3.650	36.667	0.587	1.077	0.030	ppbv
4-Methyl-1-pentene	0.084	0.215	0.215	0.168	0.215	0.072	ppbv
Acetylene	0.468	0.384	0.685	0.206	0.272	0.055	ppbv
a-Pinene	1.100	0.335	5.550	0.058	0.067	0.032	ppbv
Benzene	4.433	1.867	21.500	0.295	0.473	0.040	ppbv
b-Pinene	0.267	0.037	1.610	0.100	0.100	0.020	ppbv
cis-2-Butene	0.049	0.095	0.086	0.095	0.095	0.048	ppbv
cis-2-Hexene	0.215	0.215	0.215	0.215	0.215	0.072	ppbv
cis-2-Pentene	0.095	0.095	0.052	0.095	0.095	0.038	ppbv
Cyclohexane	15.033	5.350	59.167	1.167	1.523	0.037	ppbv
Cyclopentane	1.314	0.832	7.780	0.124	0.260	0.016	ppbv
Cyclopentene	0.124	0.062	0.068	0.046	0.062	0.040	ppbv
Ethane	720.000	535.000	1955.000	28.700	147.500	0.045	ppbv

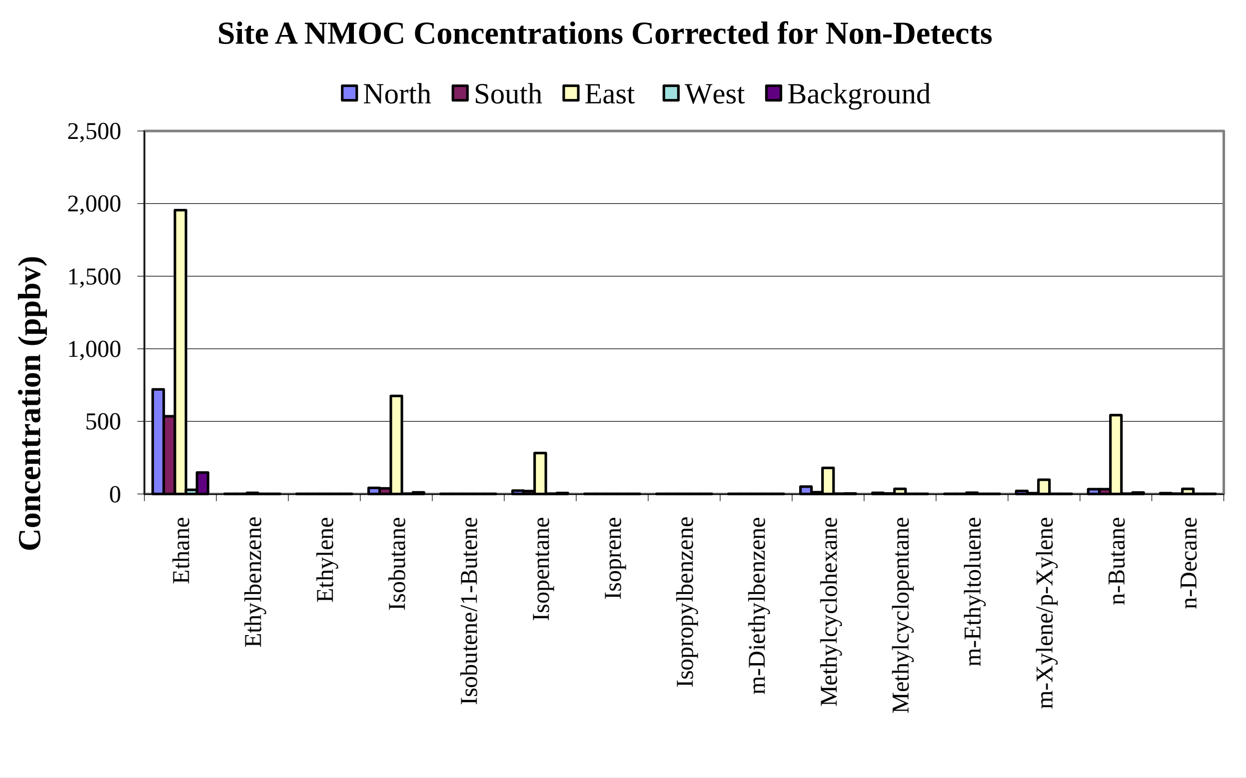
	Results						
Analyte	**North**	**South**	**East**	**West**	**Background**	**DL**	**Units**
Ethylbenzene	1.738	0.426	7.363	0.084	0.092	0.026	ppbv
Ethylene	0.780	0.680	1.155	0.278	0.359	0.035	ppbv
Isobutane	41.750	38.750	675.000	2.333	10.900	0.020	ppbv
Isobutene/1-Butene	0.070	0.070	0.070	0.535	1.063	0.035	ppbv
Isopentane	23.200	20.400	282.000	2.620	6.640	0.034	ppbv
Isoprene	0.066	0.075	0.100	0.063	0.100	0.040	ppbv
Isopropylbenzene	0.150	0.053	0.987	0.160	0.160	0.036	ppbv
m-Diethylbenzene	0.218	0.072	1.290	0.090	0.020	0.018	ppbv
Methylcyclohexane	50.286	12.571	180.000	2.857	2.900	0.021	ppbv
Methylcyclopentane	8.083	3.633	34.833	0.703	1.115	0.022	ppbv
m-Ethyltoluene	1.722	0.467	9.056	0.079	0.097	0.017	ppbv
m-Xylene/p-Xylene	21.500	5.163	98.625	0.921	0.951	0.039	ppbv
n-Butane	32.750	33.250	542.500	2.550	9.800	0.028	ppbv
n-Decane	5.690	1.780	35.800	0.223	0.354	0.020	ppbv
n-Dodecane	1.467	0.550	7.392	0.077	0.118	0.035	ppbv
n-Heptane	22.286	5.314	74.286	1.187	1.169	0.029	ppbv
n-Hexane	15.483	7.200	72.333	1.297	2.167	0.038	ppbv
n-Nonane	11.667	2.878	57.778	0.497	0.538	0.019	ppbv
n-Octane	23.875	5.163	89.375	1.093	0.958	0.030	ppbv
n-Pentane	17.020	13.720	165.600	1.338	4.080	0.020	ppbv
n-Propylbenzene	0.558	0.162	2.433	0.032	0.033	0.021	ppbv
n-Tridecane	0.408	0.122	1.200	0.210	0.210	0.032	ppbv
n-Undecane	2.882	1.082	18.909	0.128	0.229	0.015	ppbv
o-Ethyltoluene	1.022	0.344	5.933	0.047	0.062	0.032	ppbv
o-Xylene	3.238	0.809	14.625	0.155	0.156	0.021	ppbv
p-Diethylbenzene	0.139	0.051	0.913	0.025	0.060	0.012	ppbv
p-Ethyltoluene	1.344	0.374	6.556	0.056	0.072	0.029	ppbv
Propane	155.7	143.000	2593.333	7.633	40.667	0.060	ppbv
Propylene	0.245	0.217	0.367	0.095	0.121	0.023	ppbv
Propyne	0.090	0.090	0.090	0.090	0.090	0.060	ppbv
Styrene	0.054	0.125	0.246	0.125	0.125	0.031	ppbv
Toluene	22.000	5.529	84.571	1.060	1.206	0.047	ppbv
trans-2-Butene	0.048	0.048	0.065	0.036	0.065	0.033	ppbv
trans-2-Hexene	0.215	0.215	0.215	0.215	0.215	0.072	ppbv
trans-2-Pentene	0.054	0.044	0.107	0.095	0.095	0.038	ppbv
SNMOC (Sum of Knowns)	4510	2590	27700	244	708		ppbC
Sum of Unknowns	738	225	3080	55	55		ppbC
TNMOC	5250	2810	30800	300	763		ppbC


Site A NMOC Concentrations Corrected for Non-Detects
North
South
East
West
Background
Concentration (ppbv)
0
2
4
6
8
10
12
14
16
18
1,2,3-Trimethylbenzene
1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene
1,3-Butadiene
1-Decene
1-Dodecene
1-Heptene
1-Hexene
1-Nonene
1-Octene
1-Pentene
1-Tridecene
1-Undecene

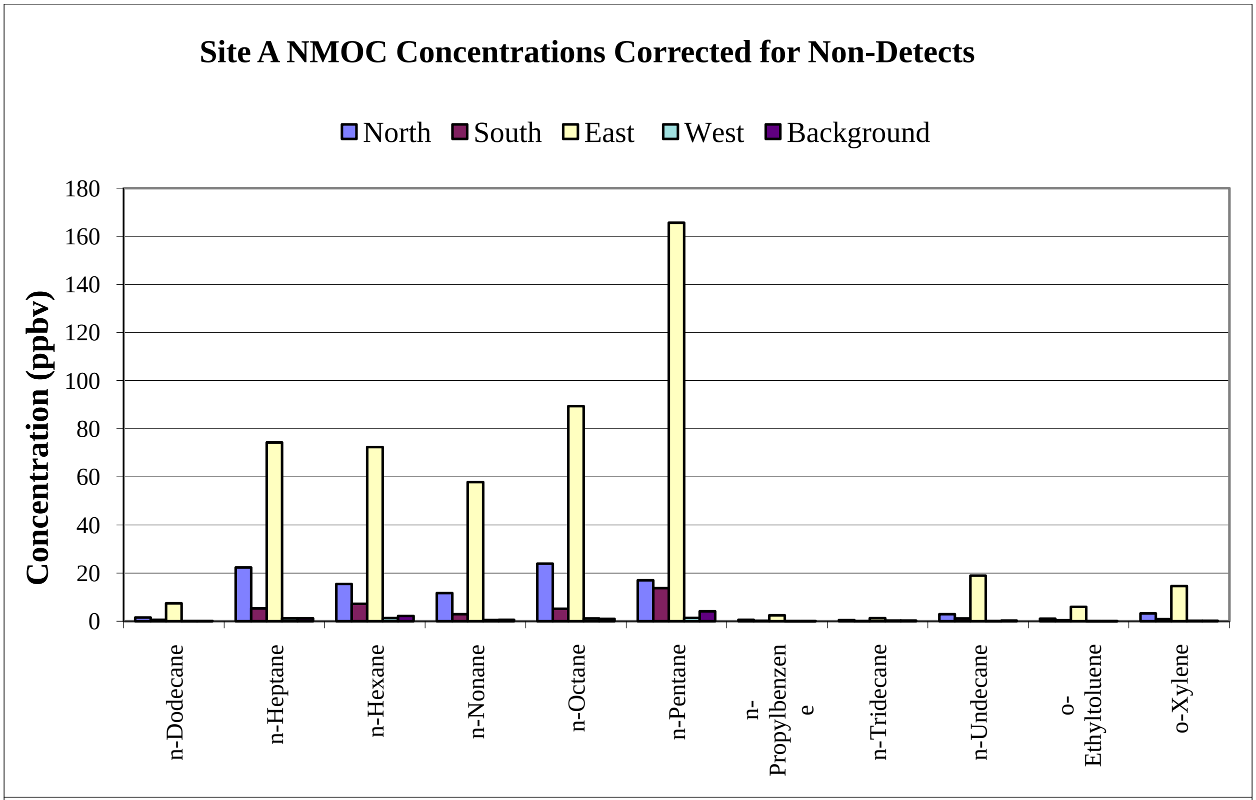

Site A NMOC Concentrations Corrected for Non-Detects
North
South
East
West
Background
Concentration (ppbv)
0
10
20
30
40
50
60
70
2,2,3-Trimethylpe…
2,2,4-Trimethylpe…
2,2-Dimethylbu…
2,3,4-Trimethylpe…
2,3-Dimethylbu…
2,3-Dimethylpe…
2,4-Dimethylpe…
2-Ethyl-1-butene
2-Methyl-1-butene
2-Methyl-1-pentene
2-Methyl-2-butene
2-Methylheptane
2-Methylhexane
2-Methylpentane

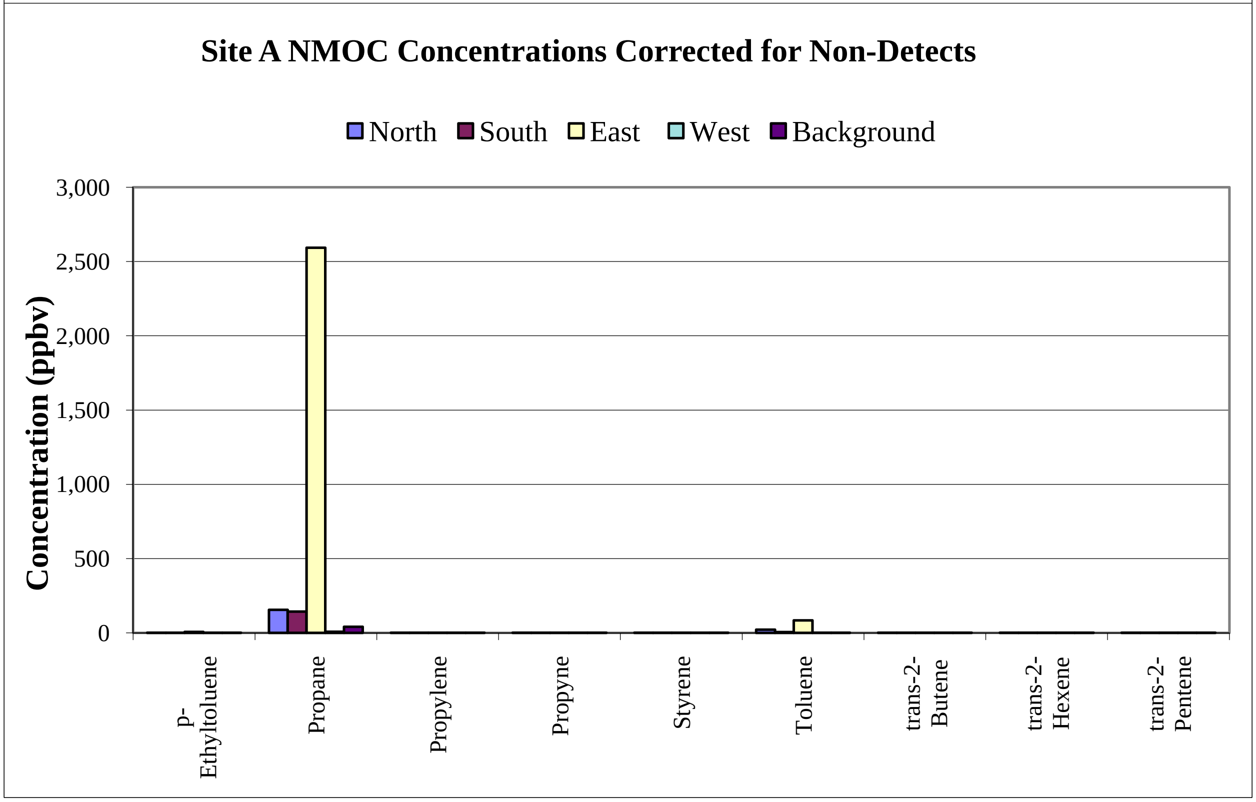


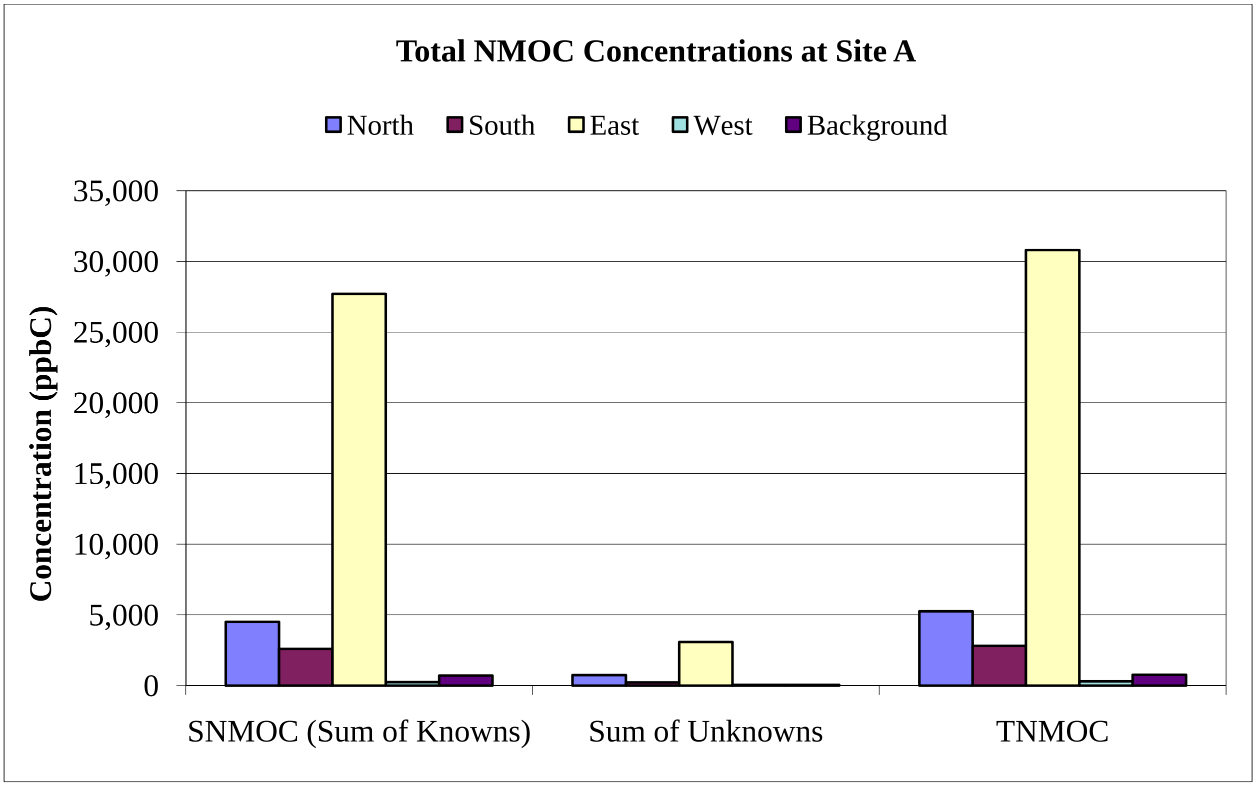
Site A NMOC Concentrations Corrected for Non-Detects



Site A NMOC Concentrations Corrected for Non-Detects


Site A NMOC Concentrations Corrected for Non-Detects
North
South
East
West
Background
Concentration (ppbv)
180
160
140
120
100
80
60
40
20
0
n-Dodecane
n-Heptane
n-Hexane
n-Nonane
n-Octane
n-Pentane
n-Propylbenzene
n-Tridecane
n-Undecane
o-Ethyltoluene
o-Xylene


Site A NMOC Concentrations Corrected for Non-Detects
North
South
East
West
Background
Concentration (ppbv)
3,000
2,500
2,000
1,500
1,000
500
0
p-Ethyltoluene
Propane
Propylene
Propyne
Styrene
Toluene
trans-2-Butene
trans-2-Hexene
trans-2-Pentene

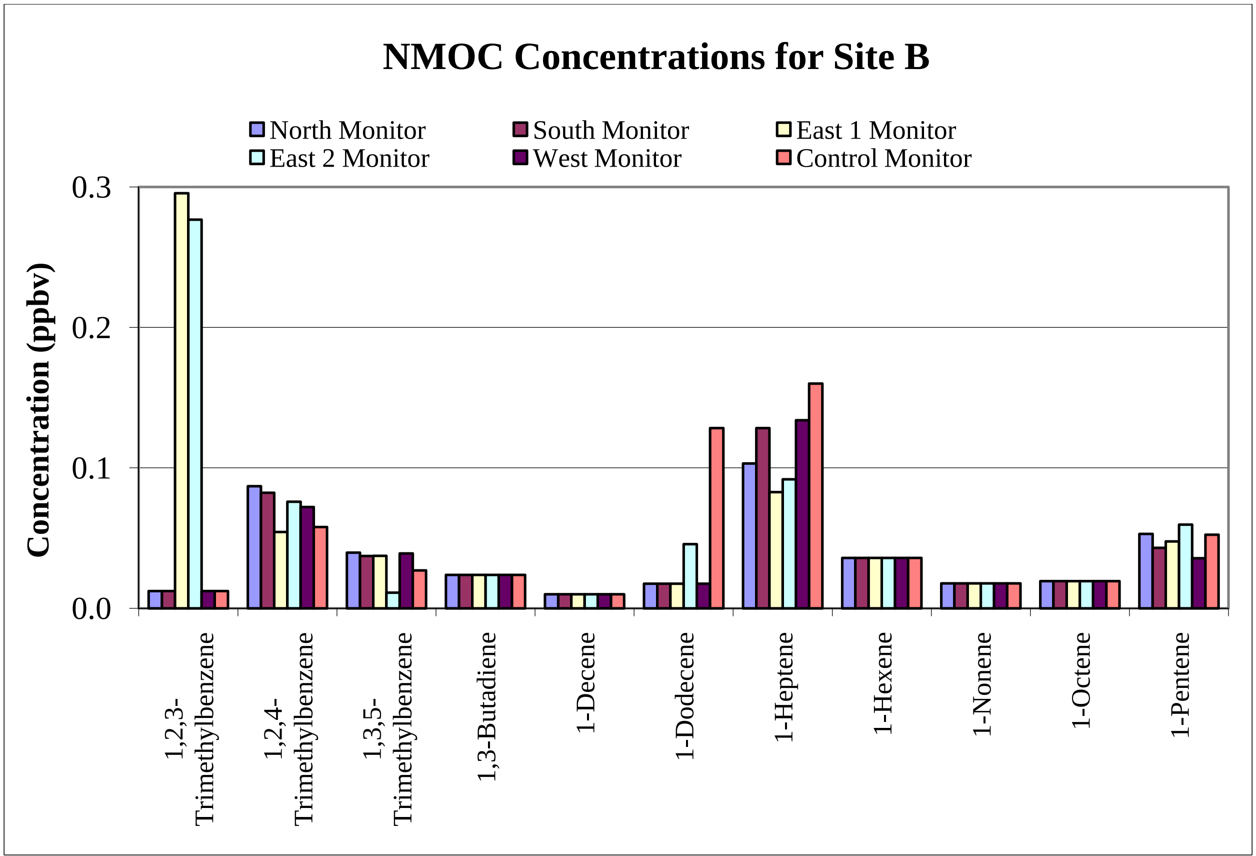

Total NMOC Concentrations at Site A
North
South
East
West
Background
Concentration (ppbC)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
SNMOC (Sum of Knowns)
Sum of Unknowns
TNMOC

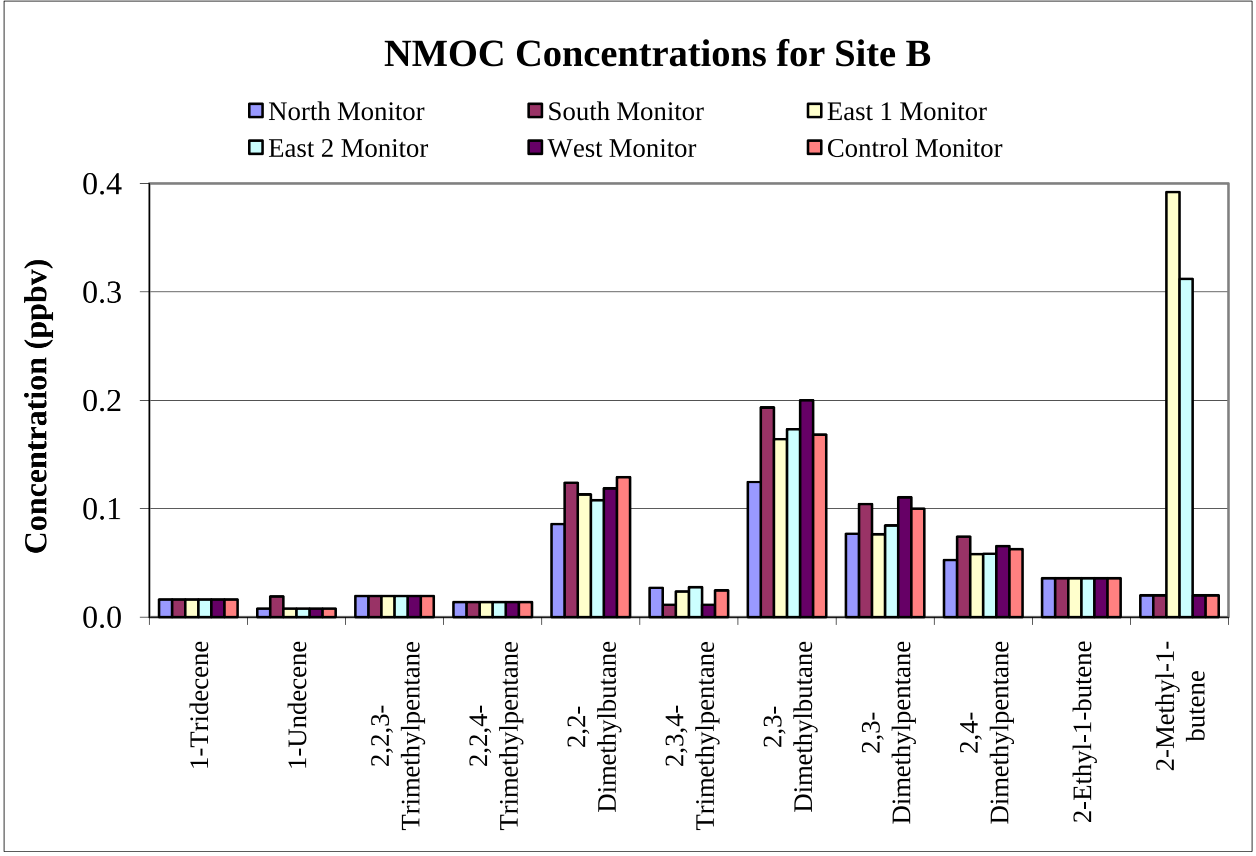
APPENDIX B – SITE B NMOC DATA AND GRAPHS

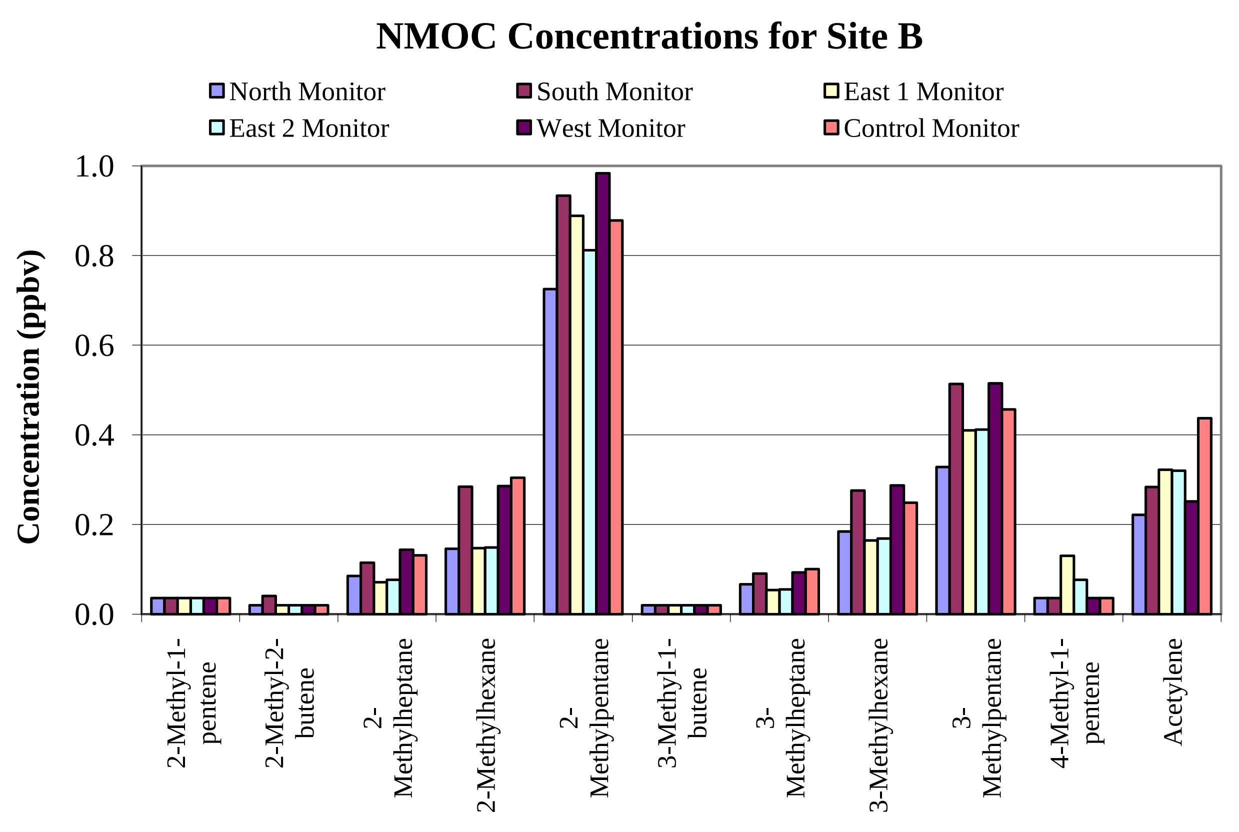
*****NOTE – All table and graph values represent 27 hour sampling periods.***

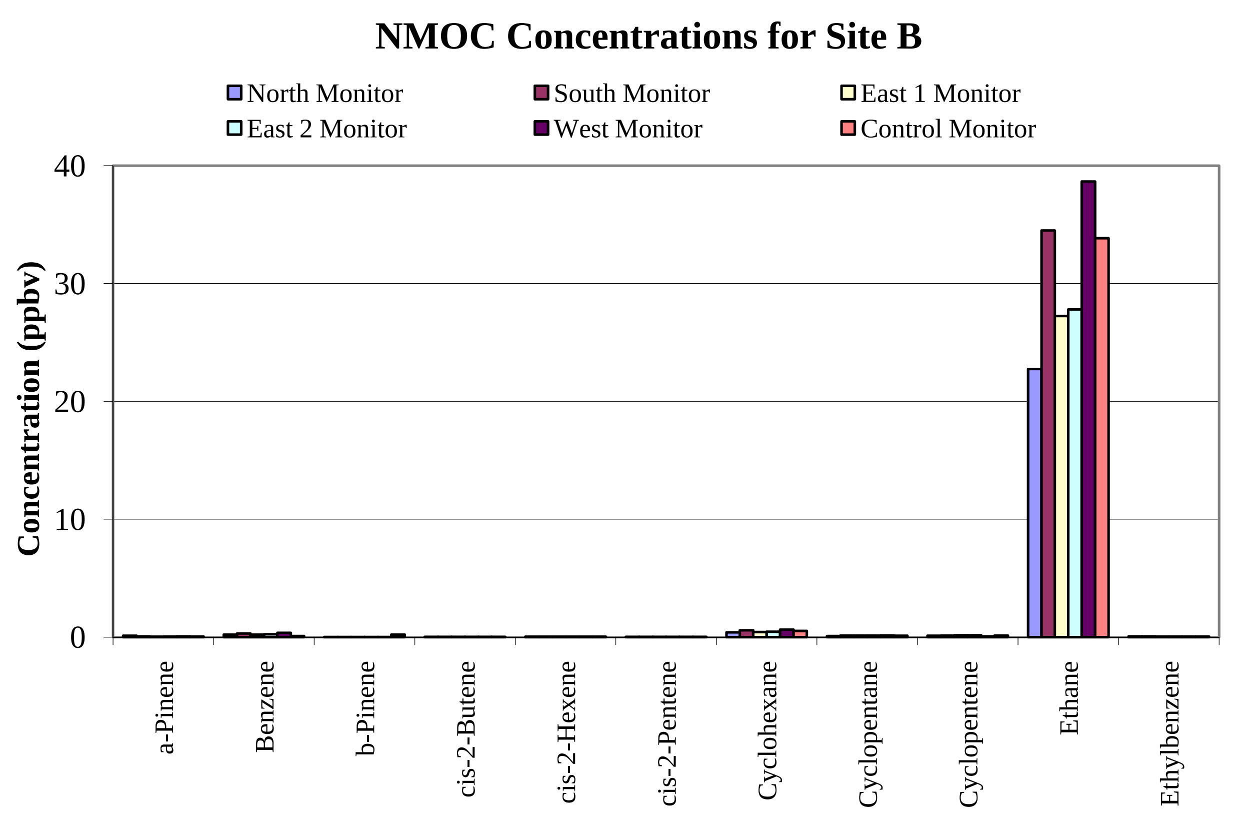
	Results							
ANALYTE	**North**	**South**	**East 1**	**East 2**	**West**	**Background**	**DL**	**UNITS**
1,2,3-Trimethylbenzene	0.012	0.012	0.296	0.277	0.012	0.012	0.024	ppbv
1,2,4-Trimethylbenzene	0.087	0.082	0.054	0.076	0.072	0.058	0.027	ppbv
1,3,5-Trimethylbenzene	0.040	0.037	0.037	0.011	0.039	0.027	0.022	ppbv
1,3-Butadiene	0.024	0.024	0.024	0.024	0.024	0.024	0.048	ppbv
1-Decene	0.010	0.010	0.010	0.010	0.010	0.010	0.020	ppbv
1-Dodecene	0.018	0.018	0.018	0.046	0.018	0.128	0.035	ppbv
1-Heptene	0.103	0.128	0.083	0.092	0.134	0.160	0.056	ppbv
1-Hexene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
1-Nonene	0.018	0.018	0.018	0.018	0.018	0.018	0.036	ppbv
1-Octene	0.019	0.019	0.019	0.019	0.019	0.019	0.039	ppbv
1-Pentene	0.053	0.043	0.048	0.060	0.036	0.052	0.024	ppbv
1-Tridecene	0.016	0.016	0.016	0.016	0.016	0.016	0.032	ppbv
1-Undecene	0.008	0.019	0.008	0.008	0.008	0.008	0.015	ppbv
2,2,3-Trimethylpentane	0.019	0.019	0.019	0.019	0.019	0.019	0.039	ppbv
2,2,4-Trimethylpentane	0.014	0.014	0.014	0.014	0.014	0.014	0.028	ppbv
2,2-Dimethylbutane	0.086	0.124	0.113	0.108	0.119	0.129	0.023	ppbv
2,3,4-Trimethylpentane	0.027	0.011	0.024	0.028	0.011	0.025	0.023	ppbv
2,3-Dimethylbutane	0.125	0.193	0.164	0.173	0.200	0.168	0.033	ppbv
2,3-Dimethylpentane	0.077	0.104	0.076	0.084	0.110	0.100	0.056	ppbv
2,4-Dimethylpentane	0.053	0.074	0.058	0.058	0.065	0.063	0.034	ppbv
2-Ethyl-1-butene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
2-Methyl-1-butene	0.020	0.020	0.392	0.312	0.020	0.020	0.040	ppbv
2-Methyl-1-pentene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
2-Methyl-2-butene	0.020	0.041	0.020	0.020	0.020	0.020	0.040	ppbv
2-Methylheptane	0.085	0.115	0.071	0.077	0.144	0.131	0.023	ppbv
2-Methylhexane	0.146	0.284	0.147	0.149	0.286	0.304	0.026	ppbv
2-Methylpentane	0.725	0.933	0.888	0.812	0.983	0.878	0.013	ppbv
3-Methyl-1-butene	0.020	0.020	0.020	0.020	0.020	0.020	0.040	ppbv
3-Methylheptane	0.067	0.091	0.054	0.055	0.093	0.101	0.025	ppbv
3-Methylhexane	0.184	0.276	0.164	0.169	0.287	0.249	0.033	ppbv
3-Methylpentane	0.328	0.513	0.410	0.412	0.515	0.457	0.030	ppbv
4-Methyl-1-pentene	0.036	0.036	0.130	0.077	0.036	0.036	0.072	ppbv
Acetylene	0.222	0.284	0.322	0.320	0.252	0.437	0.055	ppbv
a-Pinene	0.120	0.058	0.037	0.047	0.065	0.042	0.032	ppbv
Benzene	0.210	0.308	0.207	0.243	0.362	0.083	0.040	ppbv
b-Pinene	0.010	0.010	0.010	0.010	0.010	0.206	0.020	ppbv
cis-2-Butene	0.024	0.024	0.024	0.024	0.024	0.024	0.048	ppbv
cis-2-Hexene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
cis-2-Pentene	0.019	0.019	0.019	0.019	0.019	0.019	0.038	ppbv
Cyclohexane	0.400	0.577	0.430	0.450	0.627	0.527	0.037	ppbv
Cyclopentane	0.092	0.131	0.132	0.125	0.137	0.114	0.016	ppbv
Cyclopentene	0.110	0.125	0.156	0.161	0.064	0.124	0.040	ppbv
Ethane	22.8	34.5	27.3	27.8	38.7	33.9	0.045	ppbv

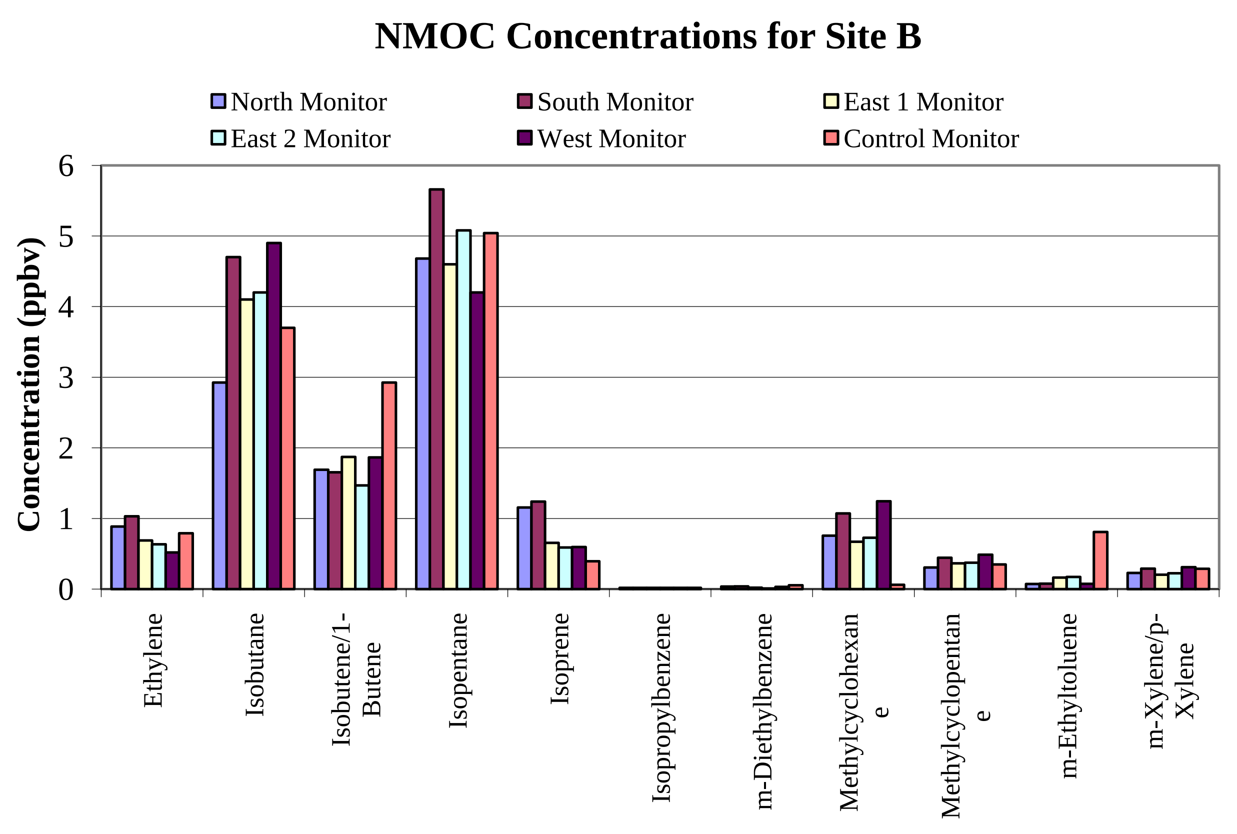
	Results							
ANALYTE	**North**	**South**	**East 1**	**East 2**	**West**	**Background**	**DL**	**UNITS**
Ethylbenzene	0.061	0.057	0.045	0.044	0.052	0.044	0.026	ppbv
Ethylene	0.885	1.030	0.690	0.635	0.520	0.790	0.035	ppbv
Isobutane	2.925	4.700	4.100	4.200	4.900	3.700	0.020	ppbv
Isobutene/1-Butene	1.690	1.655	1.873	1.468	1.865	2.925	0.035	ppbv
Isopentane	4.680	5.660	4.600	5.080	4.200	5.040	0.034	ppbv
Isoprene	1.156	1.240	0.656	0.590	0.596	0.394	0.040	ppbv
Isopropylbenzene	0.018	0.018	0.018	0.018	0.018	0.018	0.036	ppbv
m-Diethylbenzene	0.036	0.038	0.021	0.009	0.033	0.054	0.018	ppbv
Methylcyclohexane	0.757	1.073	0.670	0.727	1.243	0.062	0.021	ppbv
Methylcyclopentane	0.305	0.443	0.365	0.375	0.488	0.350	0.022	ppbv
m-Ethyltoluene	0.072	0.078	0.164	0.173	0.075	0.809	0.017	ppbv
m-Xylene/p-Xylene	0.230	0.291	0.205	0.225	0.310	0.289	0.039	ppbv
n-Butane	3.150	5.025	4.600	4.700	5.225	3.800	0.028	ppbv
n-Decane	0.194	0.153	0.132	0.142	0.141	0.114	0.020	ppbv
n-Dodecane	0.057	0.050	0.118	0.135	0.051	0.018	0.035	ppbv
n-Heptane	0.363	0.501	0.294	0.317	0.571	0.486	0.029	ppbv
n-Hexane	0.713	1.053	0.782	0.845	1.127	0.902	0.038	ppbv
n-Nonane	0.113	0.129	0.082	0.101	0.156	0.123	0.019	ppbv
n-Octane	0.228	0.295	0.209	0.186	0.361	0.361	0.030	ppbv
n-Pentane	1.396	2.160	1.892	1.934	2.320	1.806	0.020	ppbv
n-Propylbenzene	0.024	0.023	0.011	0.029	0.011	0.011	0.021	ppbv
n-Tridecane	0.016	0.016	0.034	0.061	0.016	0.016	0.032	ppbv
n-Undecane	0.285	0.195	0.195	0.187	0.165	0.120	0.015	ppbv
o-Ethyltoluene	0.034	0.054	0.016	0.047	0.016	0.016	0.032	ppbv
o-Xylene	0.099	0.096	0.066	0.077	0.091	0.074	0.021	ppbv
p-Diethylbenzene	0.006	0.015	0.006	0.006	0.014	0.012	0.012	ppbv
p-Ethyltoluene	0.014	0.120	0.014	0.014	0.030	0.014	0.029	ppbv
Propane	10.0	15.6	14.0	14.3	16.6	12.6	0.060	ppbv
Propylene	0.201	0.213	0.265	0.289	0.175	0.252	0.023	ppbv
Propyne	0.030	0.030	0.030	0.030	0.030	0.030	0.060	ppbv
Styrene	0.016	0.016	0.016	0.016	0.016	0.016	0.031	ppbv
Toluene	0.489	0.620	0.400	0.456	0.640	0.594	0.047	ppbv
trans-2-Butene	0.045	0.040	0.059	0.058	0.045	0.075	0.033	ppbv
trans-2-Hexene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
trans-2-Pentene	0.039	0.046	0.061	0.044	0.038	0.038	0.038	ppbv
SNMOC	199	278	234	240	284	251		ppbC
Sum of Unknowns	74.7	94.7	127	210	82.5	73.4		ppbC
TNMOC	273	373	361	449	366	324		ppbC

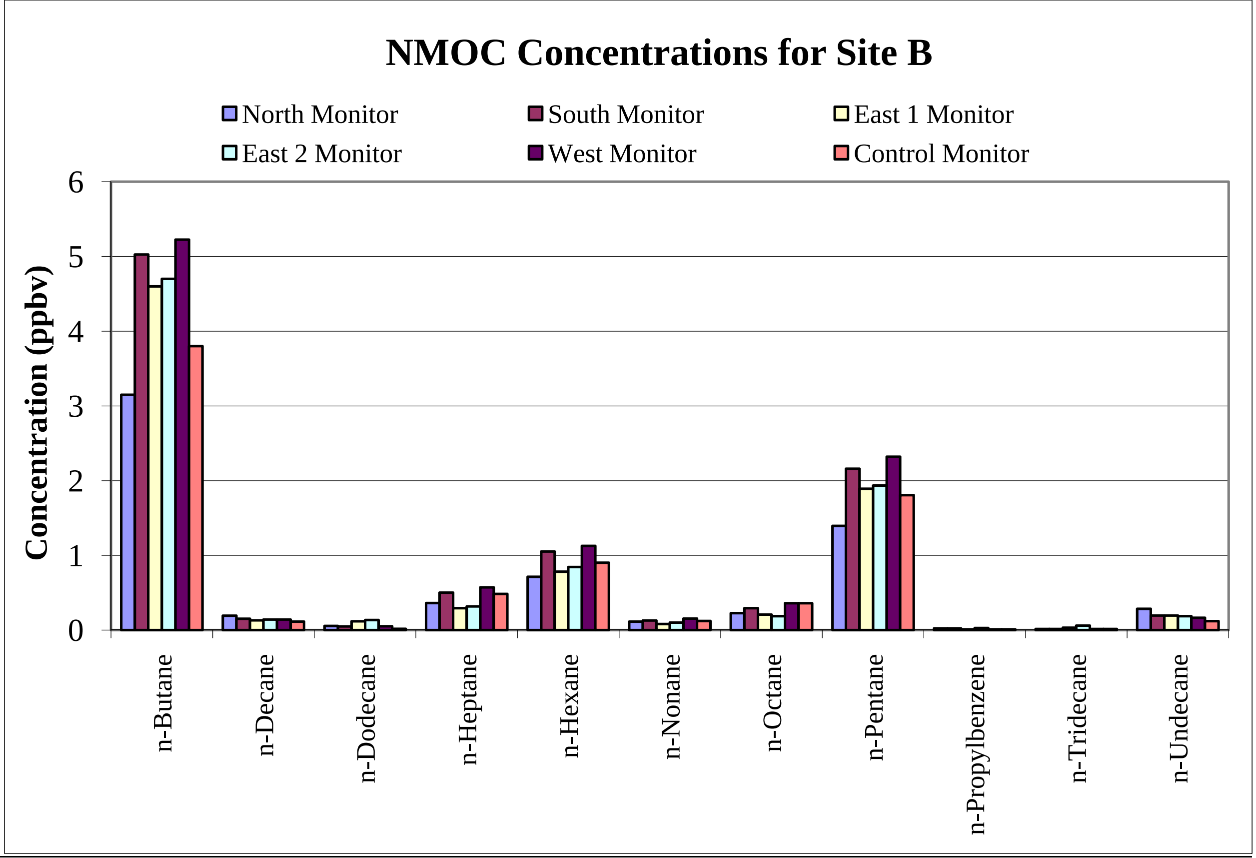

NMOC Concentrations for Site B
North Monitor
South Monitor
East 1 Monitor
East 2 Monitor
West Monitor
Control Monitor
Concentration (ppbv)
0.3
0.2
0.1
0.0
1,2,3-Trimethylbenzene
1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene
1,3-Butadiene
1-Decene
1-Dodecene
1-Heptene
1-Hexene
1-Nonene
1-Octene
1-Pentene

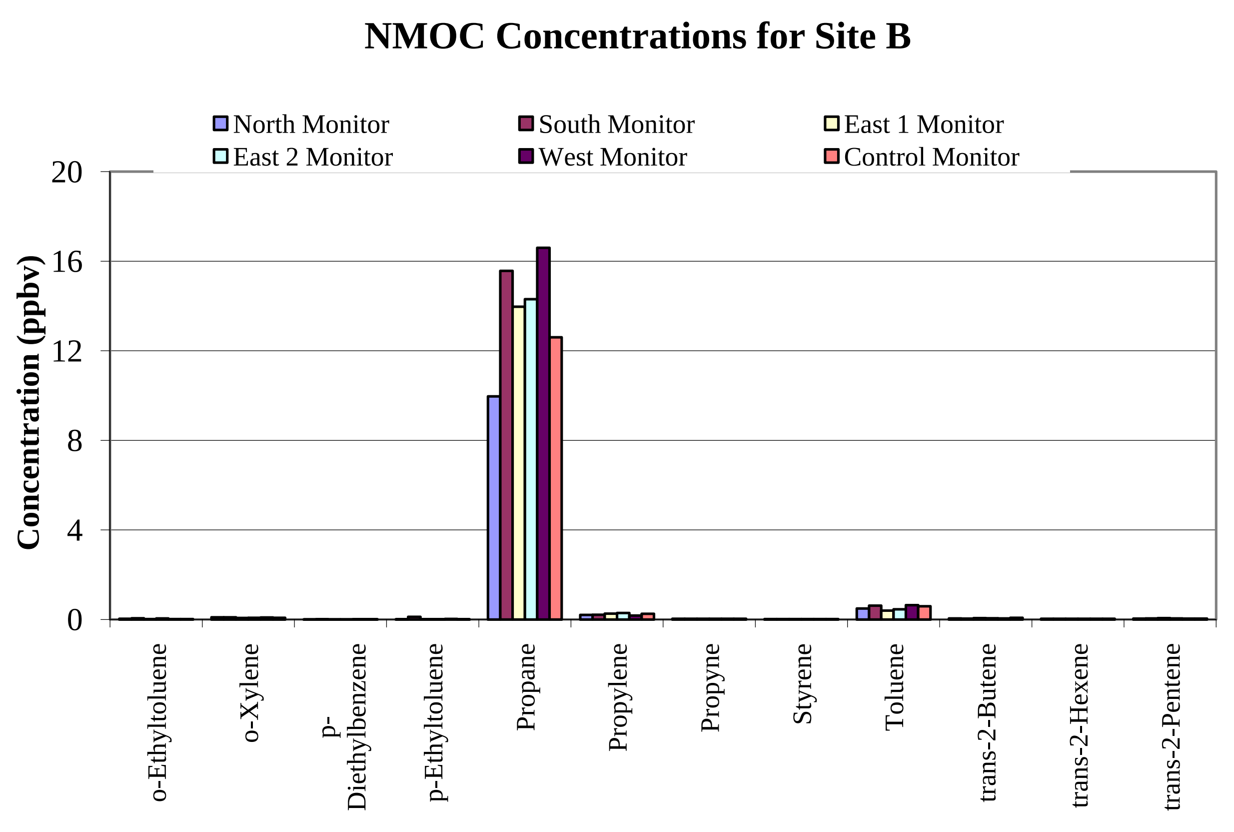

NMOC Concentrations for Site B
North Monitor
South Monitor
East 1 Monitor
East 2 Monitor
West Monitor
Control Monitor
Concentration (ppbv)
0.4
0.3
0.2
0.1
0.0
1-Tridecene
1-Undecene
2,2,3-Trimethylpentane
2,2,4-Trimethylpentane
2,2-Dimethylbutane
2,3,4-Trimethylpentane
2,3-Dimethylbutane
2,3-Dimethylpentane
2,4-Dimethylpentane
2-Ethyl-1-butene
2-Methyl-1-butene

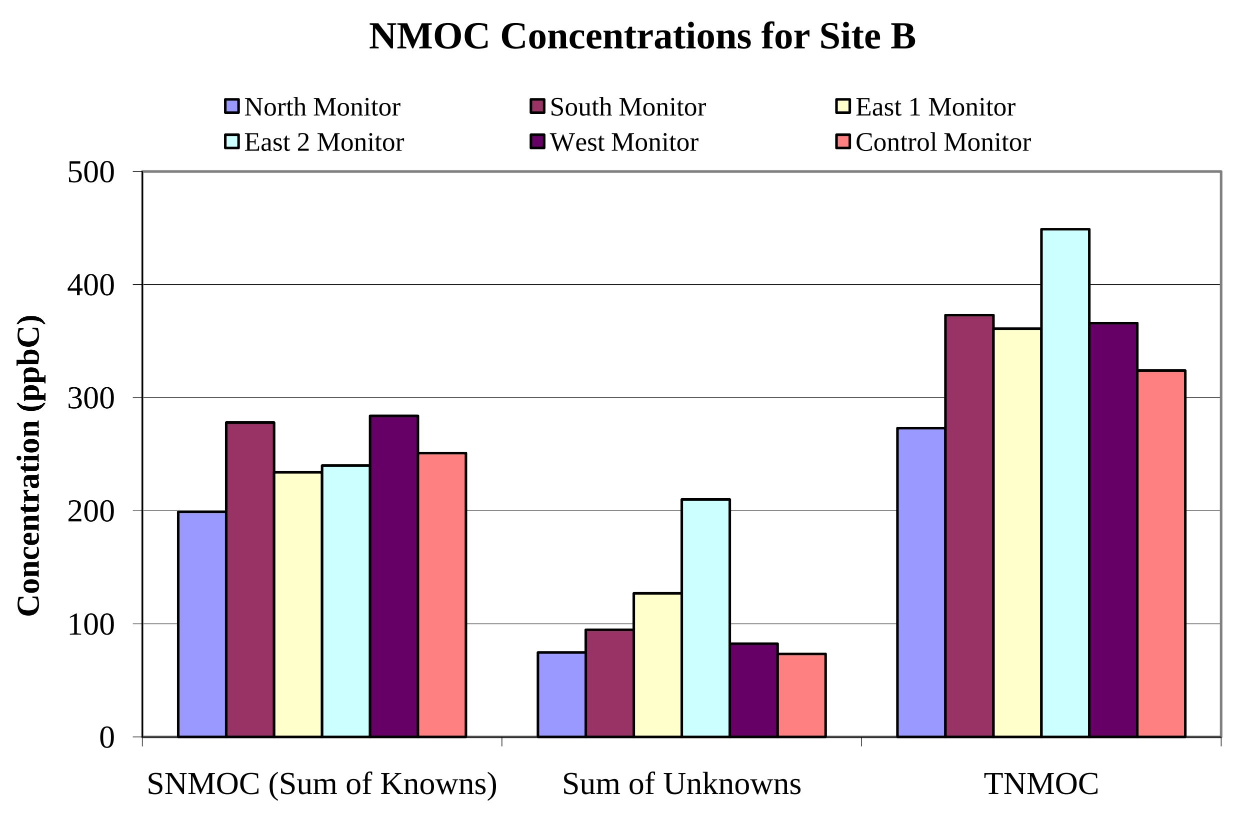

NMOC Concentrations for Site B
North Monitor
South Monitor
East 1 Monitor
East 2 Monitor
West Monitor
Control Monitor
Concentration (ppbv)
1.0
0.8
0.6
0.4
0.2
0.0
2-Methyl-1-pentene
2-Methyl-2-butene
2-Methylheptane
2-Methylhexane
2-Methylpentane
3-Methyl-1-butene
3-Methylheptane
3-Methylhexane
3-Methylpentane
4-Methyl-1-pentene
Acetylene


NMOC Concentrations for Site B
North Monitor
South Monitor
East 1 Monitor
East 2 Monitor
West Monitor
Control Monitor
Concentration (ppbv)
40
30
20
10
0
a-Pinene
Benzene
b-Pinene
cis-2-Butene
cis-2-Hexene
cis-2-Pentene
Cyclohexane
Cyclopentane
Cyclopentene
Ethane
Ethylbenzene


NMOC Concentrations for Site B
North Monitor
South Monitor
East 1 Monitor
East 2 Monitor
West Monitor
Control Monitor
Concentration (ppbv)
0
1
2
3
4
5
6
Ethylene
Isobutane
Isobutene/1-Butene
Isopentane
Isoprene
Isopropylbenzene
m-Diethylbenzene
Methylcyclohexane
Methylcyclopentane
m-Ethyltoluene
m-Xylene/p-Xylene


NMOC Concentrations for Site B
North Monitor
South Monitor
East 1 Monitor
East 2 Monitor
West Monitor
Control Monitor
Concentration (ppbv)
0
1
2
3
4
5
6
n-Butane
n-Decane
n-Dodecane
n-Heptane
n-Hexane
n-Nonane
n-Octane
n-Pentane
n-Propylbenzene
n-Tridecane
n-Undecane


NMOC Concentrations for Site B
North Monitor
South Monitor
East 1 Monitor
East 2 Monitor
West Monitor
Control Monitor
Concentration (ppbv)
20
16
12
8
4
0
o-Ethyltoluene
o-Xylene
p-Diethylbenzene
p-Ethyltoluene
Propane
Propylene
Propyne
Styrene
Toluene
trans-2-Butene
trans-2-Hexene
trans-2-Pentene

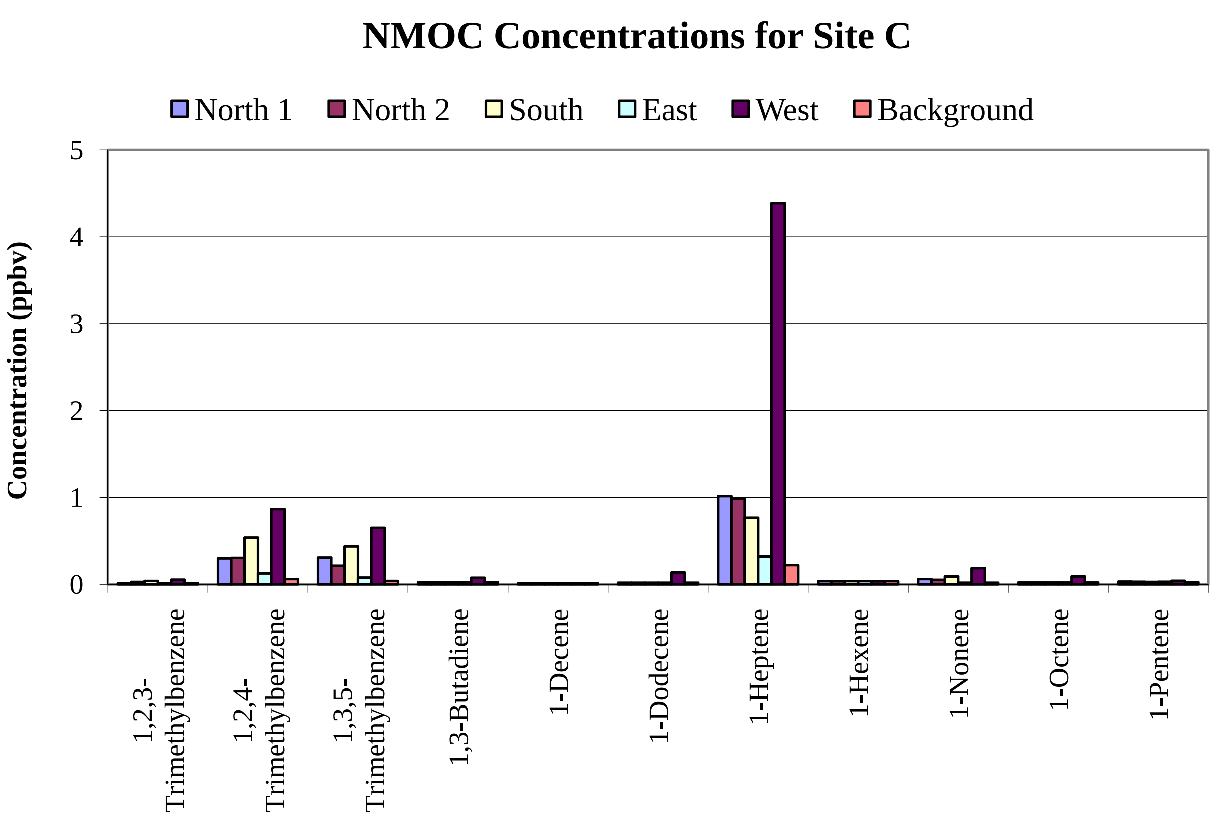

NMOC Concentrations for Site B
North Monitor
South Monitor
East 1 Monitor
East 2 Monitor
West Monitor
Control Monitor
Concentration (ppbC)
500
400
300
200
100
0
SNMOC (Sum of Knowns)
Sum of Unknowns
TNMOC

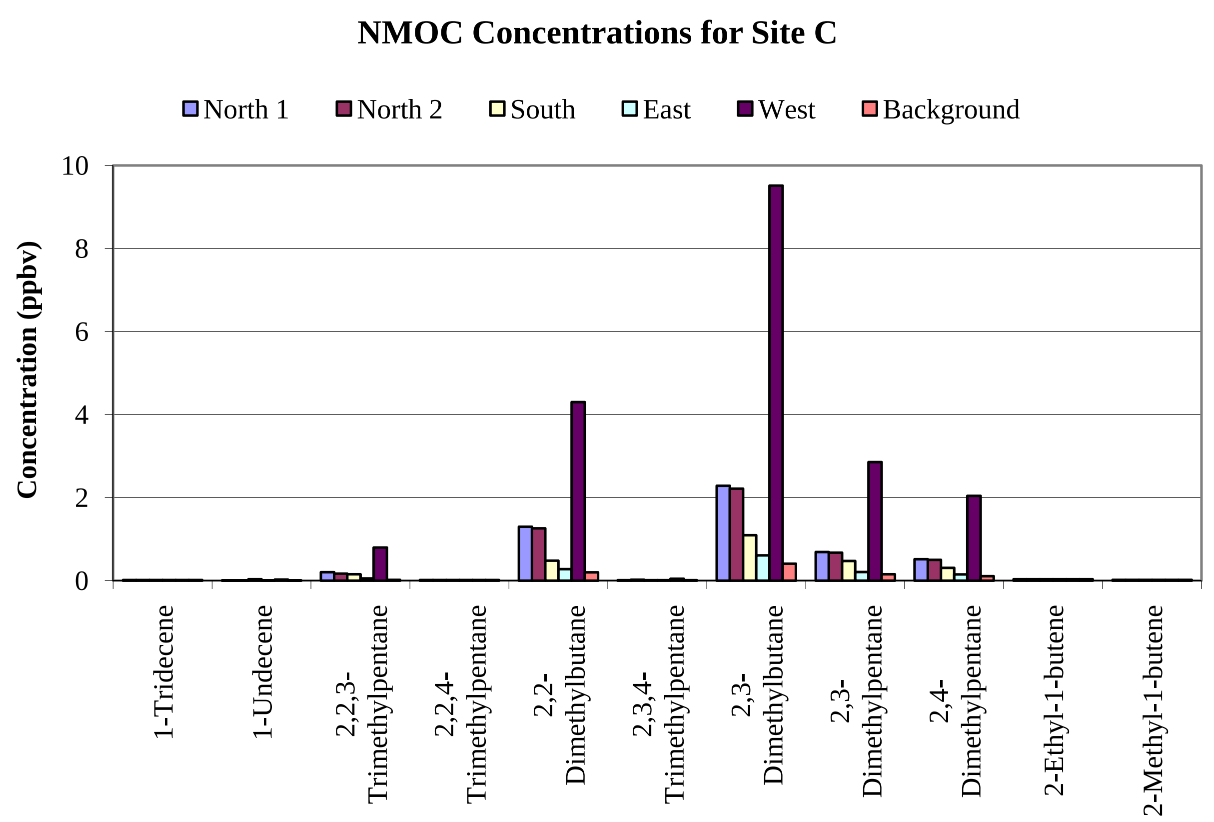
APPENDIX C – SITE C NMOC DATA AND GRAPHS

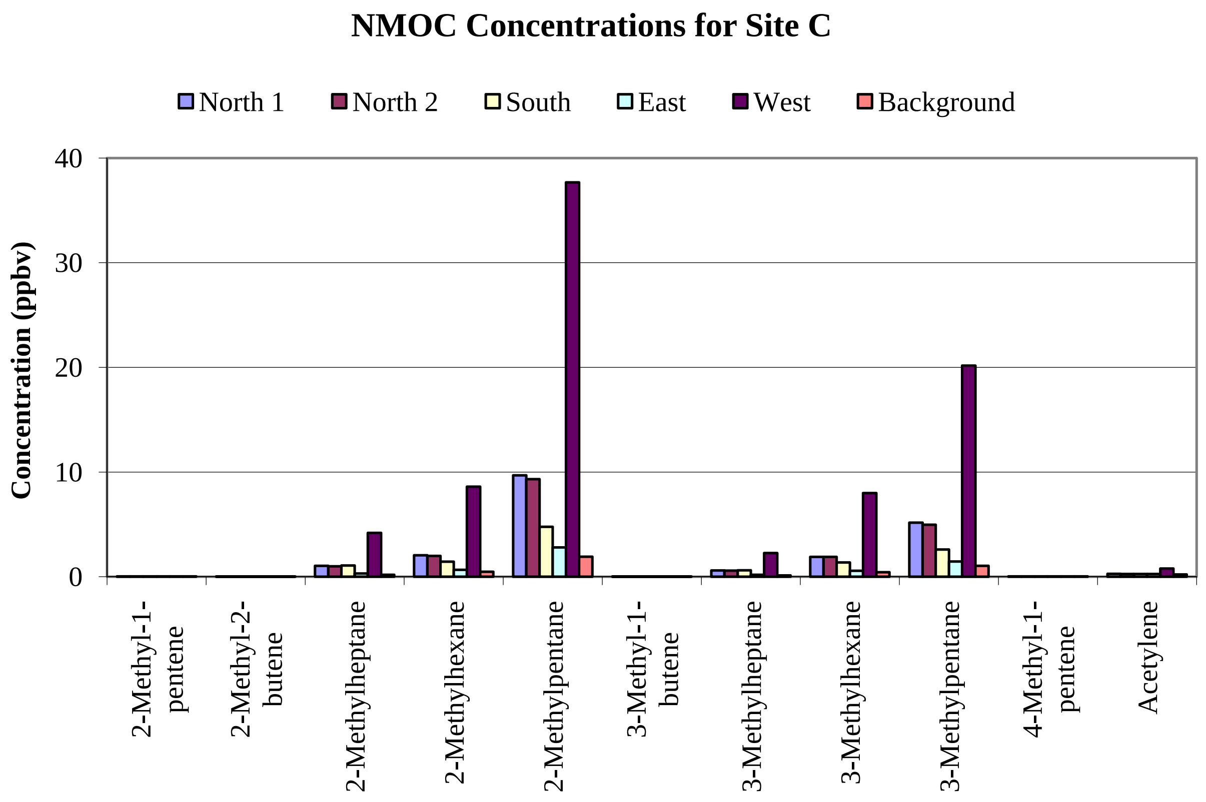
*****NOTE – All table and graph values represent 26 to 27 hour sampling periods.***

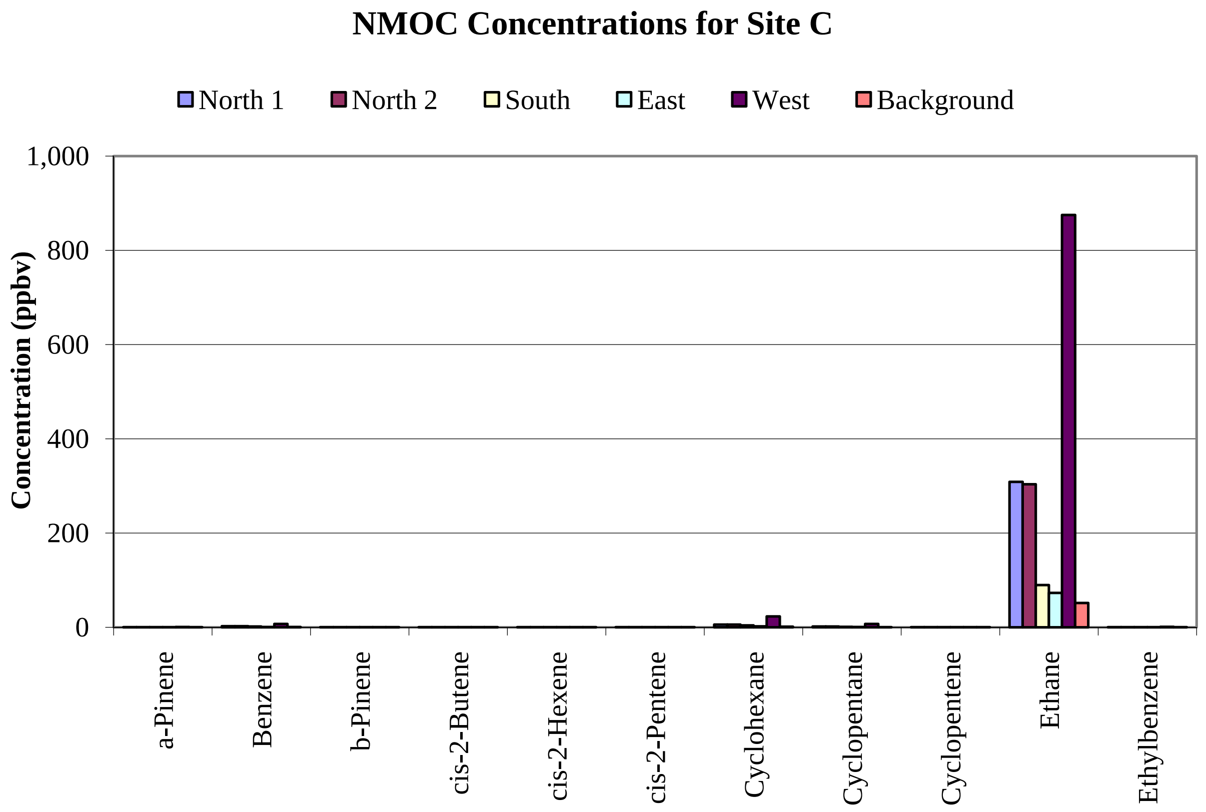
	Results							
ANALYTE	**North 1**	**North 2**	**South**	**East**	**West**	**Background**	**DL**	**UNITS**
1,2,3-Trimethylbenzene	0.012	0.028	0.039	0.012	0.052	0.012	0.024	ppbv
1,2,4-Trimethylbenzene	0.299	0.304	0.538	0.126	0.864	0.060	0.027	ppbv
1,3,5-Trimethylbenzene	0.308	0.213	0.436	0.077	0.650	0.038	0.022	ppbv
1,3-Butadiene	0.024	0.024	0.024	0.024	0.075	0.024	0.048	ppbv
1-Decene	0.010	0.010	0.010	0.010	0.010	0.010	0.020	ppbv
1-Dodecene	0.018	0.018	0.018	0.018	0.136	0.018	0.035	ppbv
1-Heptene	1.014	0.986	0.766	0.320	4.386	0.221	0.056	ppbv
1-Hexene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
1-Nonene	0.061	0.051	0.090	0.018	0.186	0.018	0.036	ppbv
1-Octene	0.019	0.019	0.019	0.019	0.090	0.019	0.039	ppbv
1-Pentene	0.032	0.029	0.028	0.029	0.040	0.025	0.024	ppbv
1-Tridecene	0.016	0.016	0.016	0.016	0.016	0.016	0.032	ppbv
1-Undecene	0.008	0.008	0.035	0.008	0.028	0.008	0.015	ppbv
2,2,3-Trimethylpentane	0.204	0.169	0.155	0.054	0.799	0.019	0.039	ppbv
2,2,4-Trimethylpentane	0.014	0.014	0.014	0.014	0.014	0.014	0.028	ppbv
2,2-Dimethylbutane	1.300	1.260	0.480	0.278	4.300	0.200	0.023	ppbv
2,3,4-Trimethylpentane	0.011	0.024	0.011	0.011	0.046	0.011	0.023	ppbv
2,3-Dimethylbutane	2.283	2.217	1.093	0.608	9.517	0.408	0.033	ppbv
2,3-Dimethylpentane	0.689	0.674	0.476	0.209	2.857	0.153	0.056	ppbv
2,4-Dimethylpentane	0.516	0.500	0.307	0.150	2.043	0.109	0.034	ppbv
2-Ethyl-1-butene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
2-Methyl-1-butene	0.020	0.020	0.020	0.020	0.020	0.020	0.040	ppbv
2-Methyl-1-pentene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
2-Methyl-2-butene	0.020	0.020	0.020	0.020	0.020	0.020	0.040	ppbv
2-Methylheptane	1.049	1.000	1.080	0.310	4.188	0.185	0.023	ppbv
2-Methylhexane	2.057	1.986	1.443	0.657	8.600	0.483	0.026	ppbv
2-Methylpentane	9.683	9.317	4.767	2.800	37.667	1.917	0.013	ppbv
3-Methyl-1-butene	0.020	0.020	0.020	0.020	0.020	0.020	0.040	ppbv
3-Methylheptane	0.598	0.578	0.620	0.184	2.263	0.121	0.025	ppbv
3-Methylhexane	1.900	1.900	1.361	0.567	8.000	0.429	0.033	ppbv
3-Methylpentane	5.167	4.967	2.600	1.457	20.167	1.035	0.030	ppbv
4-Methyl-1-pentene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
Acetylene	0.283	0.259	0.271	0.258	0.790	0.215	0.055	ppbv
a-Pinene	0.146	0.160	0.278	0.073	0.378	0.040	0.032	ppbv
Benzene	2.150	2.050	1.365	0.562	6.883	0.345	0.040	ppbv
b-Pinene	0.010	0.030	0.010	0.010	0.010	0.010	0.020	ppbv
cis-2-Butene	0.024	0.024	0.024	0.024	0.055	0.024	0.048	ppbv
cis-2-Hexene	0.081	0.077	0.080	0.079	0.072	0.084	0.072	ppbv
cis-2-Pentene	0.019	0.019	0.019	0.019	0.019	0.019	0.038	ppbv
Cyclohexane	5.733	5.533	3.983	1.783	23.000	1.173	0.037	ppbv
Cyclopentane	1.532	1.504	0.754	0.424	6.800	0.336	0.016	ppbv
Cyclopentene	0.020	0.051	0.048	0.054	0.055	0.070	0.040	ppbv
Ethane	308.5	303.5	89.5	73.0	875.0	51.5	0.045	ppbv

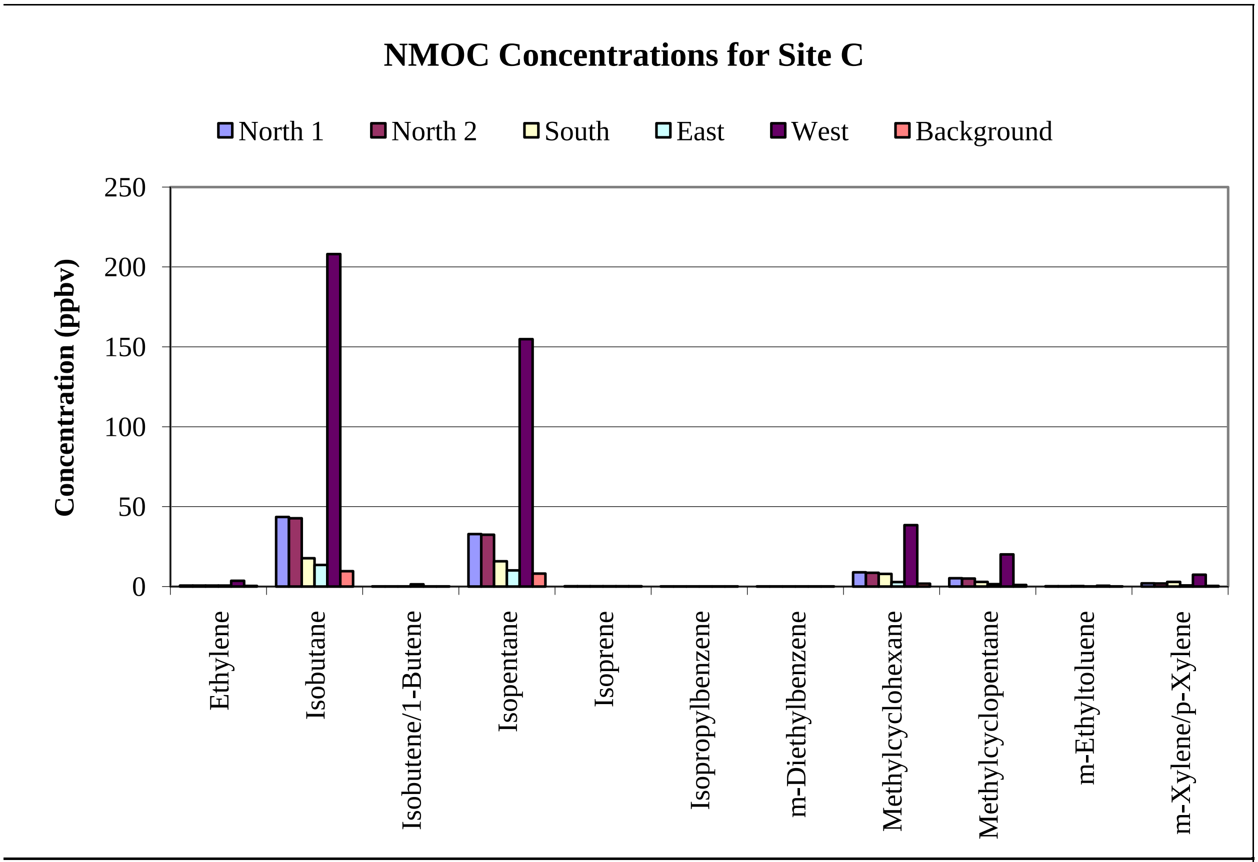
ANALYTE	Results						DL	UNITS
	North 1	North 2	South	East	West	Background		
Ethylbenzene	0.213	0.205	0.285	0.093	0.761	0.057	0.026	ppbv
Ethylene	0.640	0.610	0.625	0.640	3.660	0.451	0.035	ppbv
Isobutane	43.500	42.750	17.700	13.525	208.000	9.600	0.020	ppbv
Isobutene/1-Butene	0.018	0.018	0.018	1.425	0.018	0.018	0.035	ppbv
Isopentane	32.800	32.400	15.860	10.160	154.800	8.080	0.034	ppbv
Isoprene	0.242	0.238	0.216	0.254	0.248	0.254	0.040	ppbv
Isopropylbenzene	0.054	0.053	0.066	0.018	0.111	0.018	0.036	ppbv
m-Diethylbenzene	0.036	0.030	0.078	0.009	0.061	0.009	0.018	ppbv
Methylcyclohexane	8.900	8.614	7.886	2.843	38.429	1.786	0.021	ppbv
Methylcyclopentane	5.167	4.967	2.917	1.512	20.167	1.040	0.022	ppbv
m-Ethyltoluene	0.171	0.163	0.296	0.083	0.503	0.045	0.017	ppbv
m-Xylene/p-Xylene	2.013	1.938	2.938	0.753	7.463	0.401	0.039	ppbv
n-Butane	52.250	51.000	21.800	16.125	267.500	10.975	0.028	ppbv
n-Decane	0.590	0.588	1.170	0.229	1.320	0.134	0.020	ppbv
n-Dodecane	0.327	0.318	0.967	0.169	0.572	0.054	0.035	ppbv
n-Heptane	4.443	4.243	3.600	1.323	19.714	0.850	0.029	ppbv
n-Hexane	10.750	10.267	5.783	3.150	43.333	2.217	0.038	ppbv
n-Nonane	0.971	0.942	1.589	0.354	3.100	0.182	0.019	ppbv
n-Octane	2.338	2.238	2.900	0.788	9.263	0.540	0.030	ppbv
n-Pentane	25.600	25.400	11.320	7.060	125.000	5.020	0.020	ppbv
n-Propylbenzene	0.055	0.058	0.096	0.027	0.167	0.011	0.021	ppbv
n-Tridecane	0.108	0.087	0.332	0.046	0.202	0.016	0.032	ppbv
n-Undecane	0.456	0.453	1.200	0.232	0.831	0.126	0.015	ppbv
o-Ethyltoluene	0.122	0.117	0.191	0.045	0.238	0.016	0.032	ppbv
o-Xylene	0.369	0.348	0.538	0.140	1.275	0.080	0.021	ppbv
p-Diethylbenzene	0.006	0.022	0.006	0.012	0.006	0.006	0.012	ppbv
p-Ethyltoluene	0.126	0.116	0.219	0.051	0.418	0.014	0.029	ppbv
Propane	131.3	128.3	52.7	42.3	613.3	29.2	0.060	ppbv
Propylene	0.196	0.173	0.180	0.196	1.130	0.129	0.023	ppbv
Propyne	0.030	0.030	0.030	0.030	0.030	0.030	0.060	ppbv
Styrene	0.016	0.016	0.016	0.016	0.016	0.016	0.031	ppbv
Toluene	3.614	3.457	3.686	1.209	14.429	0.813	0.047	ppbv
trans-2-Butene	0.016	0.823	0.035	0.016	0.076	0.038	0.033	ppbv
trans-2-Hexene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
trans-2-Pentene	0.019	0.019	0.019	0.019	0.019	0.019	0.038	ppbv
SNMOC (Sum of Knowns)	2210	2160	1060	649	8920	448		ppbC
Sum of Unknowns	155	146	164	60	432	66		ppbC
TNMOC	2360	2310	1220	709	9350	513		ppbC

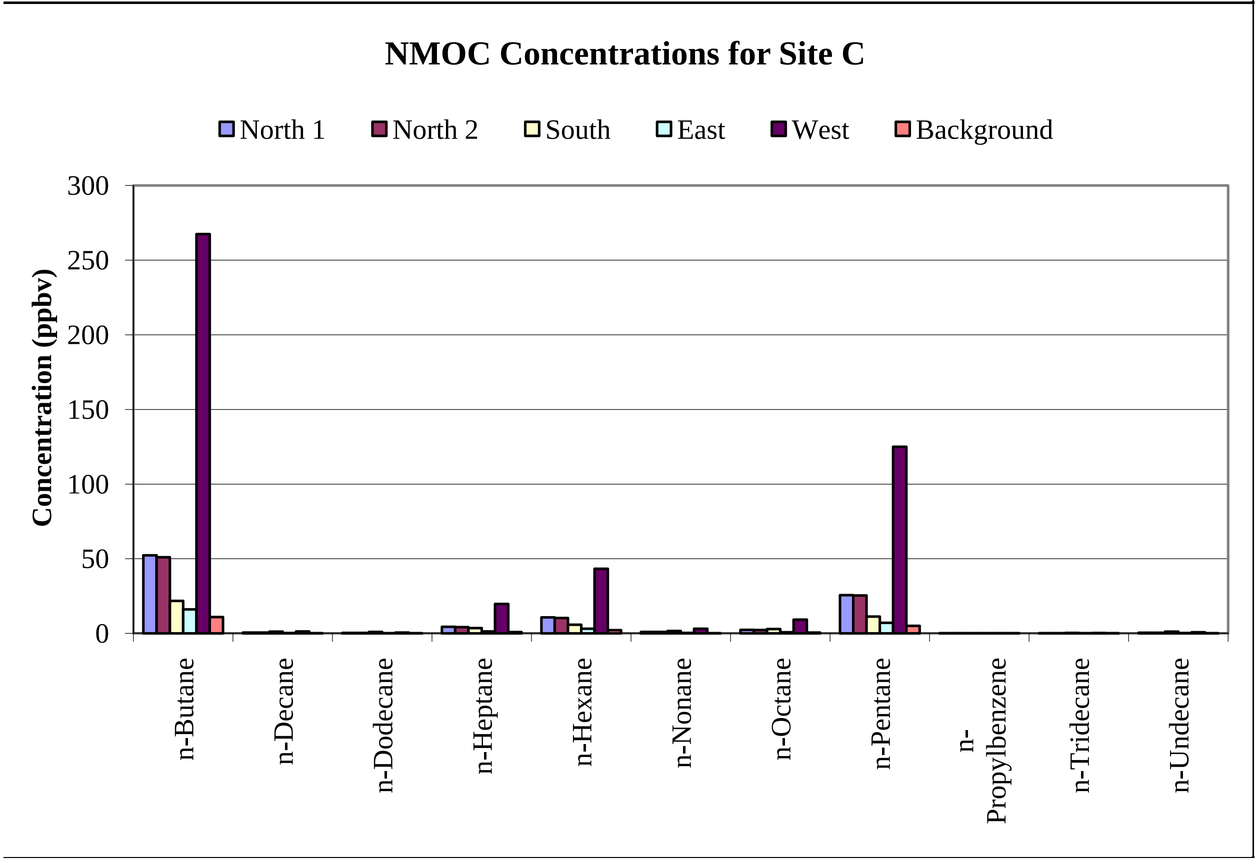

NMOC Concentrations for Site C
North 1
North 2
South
East
West
Background
Concentration (ppbv)
0
1
2
3
4
5
1,2,3-Trimethylbenzene
1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene
1,3-Butadiene
1-Decene
1-Dodecene
1-Heptene
1-Hexene
1-Nonene
1-Octene
1-Pentene

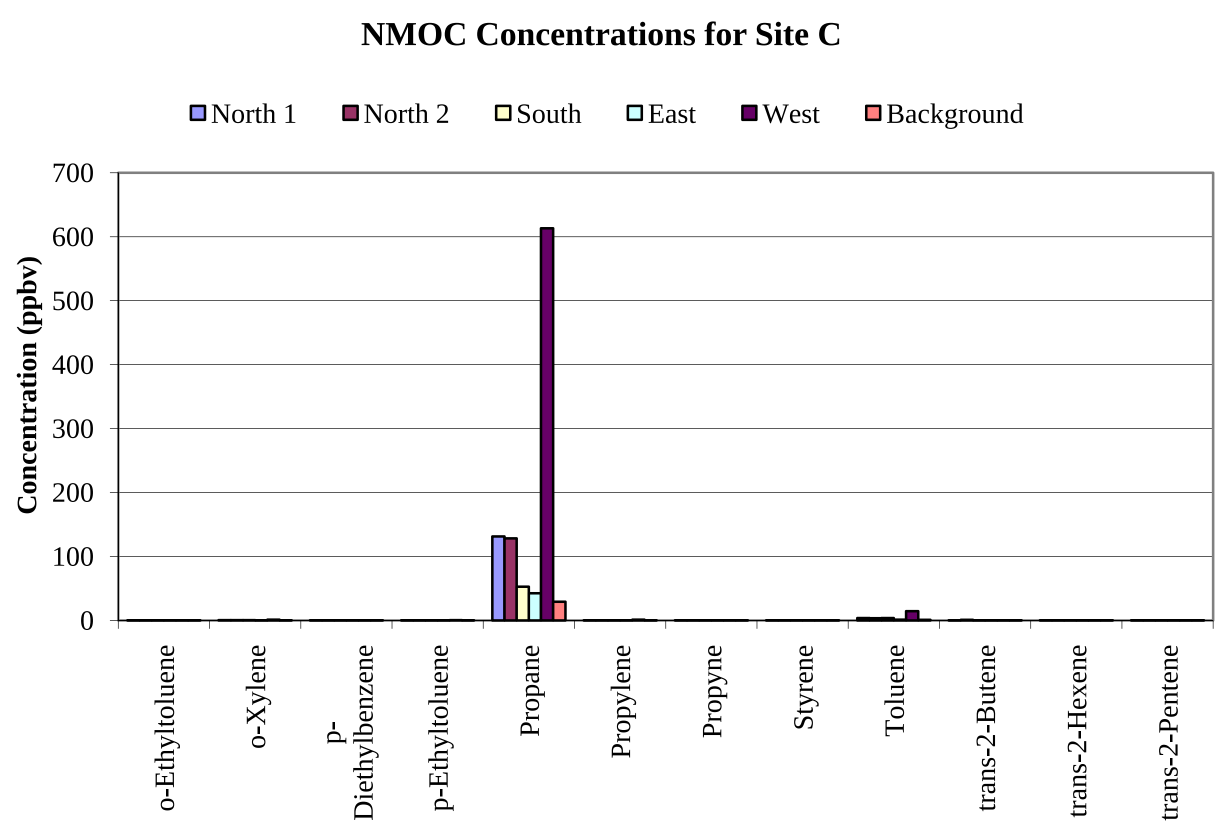

NMOC Concentrations for Site C
North 1
North 2
South
East
West
Background
Concentration (ppbv)
0
2
4
6
8
10
1-Tridecene
1-Undecene
2,2,3-Trimethylpentane
2,2,4-Trimethylpentane
2,2-Dimethylbutane
2,3,4-Trimethylpentane
2,3-Dimethylbutane
2,3-Dimethylpentane
2,4-Dimethylpentane
2-Ethyl-1-butene
2-Methyl-1-butene

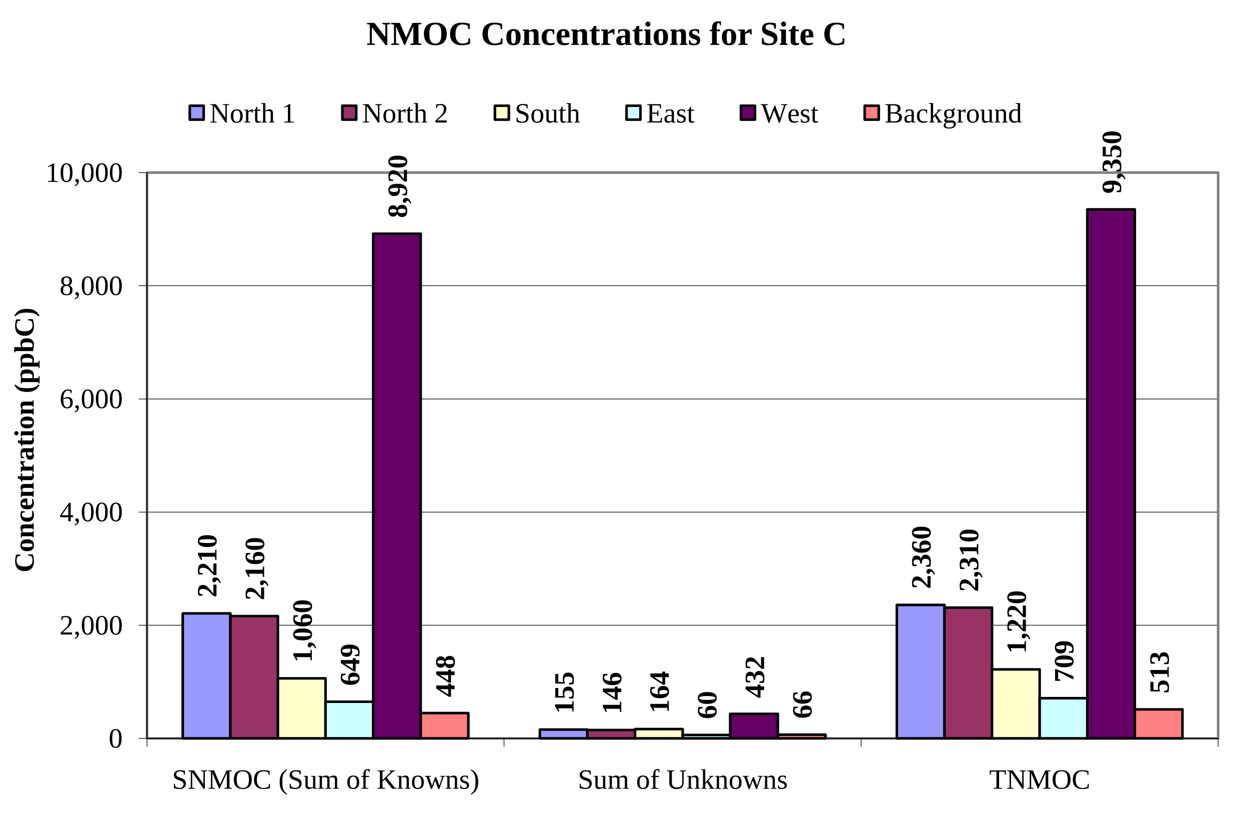

NMOC Concentrations for Site C
North 1
North 2
South
East
West
Background
Concentration (ppbv)
0
10
20
30
40
2-Methyl-1-pentene
2-Methyl-2-butene
2-Methylheptane
2-Methylhexane
2-Methylpentane
3-Methyl-1-butene
3-Methylheptane
3-Methylhexane
3-Methylpentane
4-Methyl-1-pentene
Acetylene


NMOC Concentrations for Site C
North 1
North 2
South
East
West
Background
Concentration (ppbv)
0
200
400
600
800
1,000
a-Pinene
Benzene
b-Pinene
cis-2-Butene
cis-2-Hexene
cis-2-Pentene
Cyclohexane
Cyclopentane
Cyclopentene
Ethane
Ethylbenzene


NMOC Concentrations for Site C
North 1
North 2
South
East
West
Background
Concentration (ppbv)
250
200
150
100
50
0
Ethylene
Isobutane
Isobutene/1-Butene
Isopentane
Isoprene
Isopropylbenzene
m-Diethylbenzene
Methylcyclohexane
Methylcyclopentane
m-Ethyltoluene
m-Xylene/p-Xylene


NMOC Concentrations for Site C
North 1
North 2
South
East
West
Background
Concentration (ppbv)
300
250
200
150
100
50
0
n-Butane
n-Decane
n-Dodecane
n-Heptane
n-Hexane
n-Nonane
n-Octane
n-Pentane
n-Propylbenzene
n-Tridecane
n-Undecane


NMOC Concentrations for Site C
North 1
North 2
South
East
West
Background
Concentration (ppbv)
700
600
500
400
300
200
100
0
o-Ethyltoluene
o-Xylene
p-Diethylbenzene
p-Ethyltoluene
Propane
Propylene
Propyne
Styrene
Toluene
trans-2-Butene
trans-2-Hexene
trans-2-Pentene

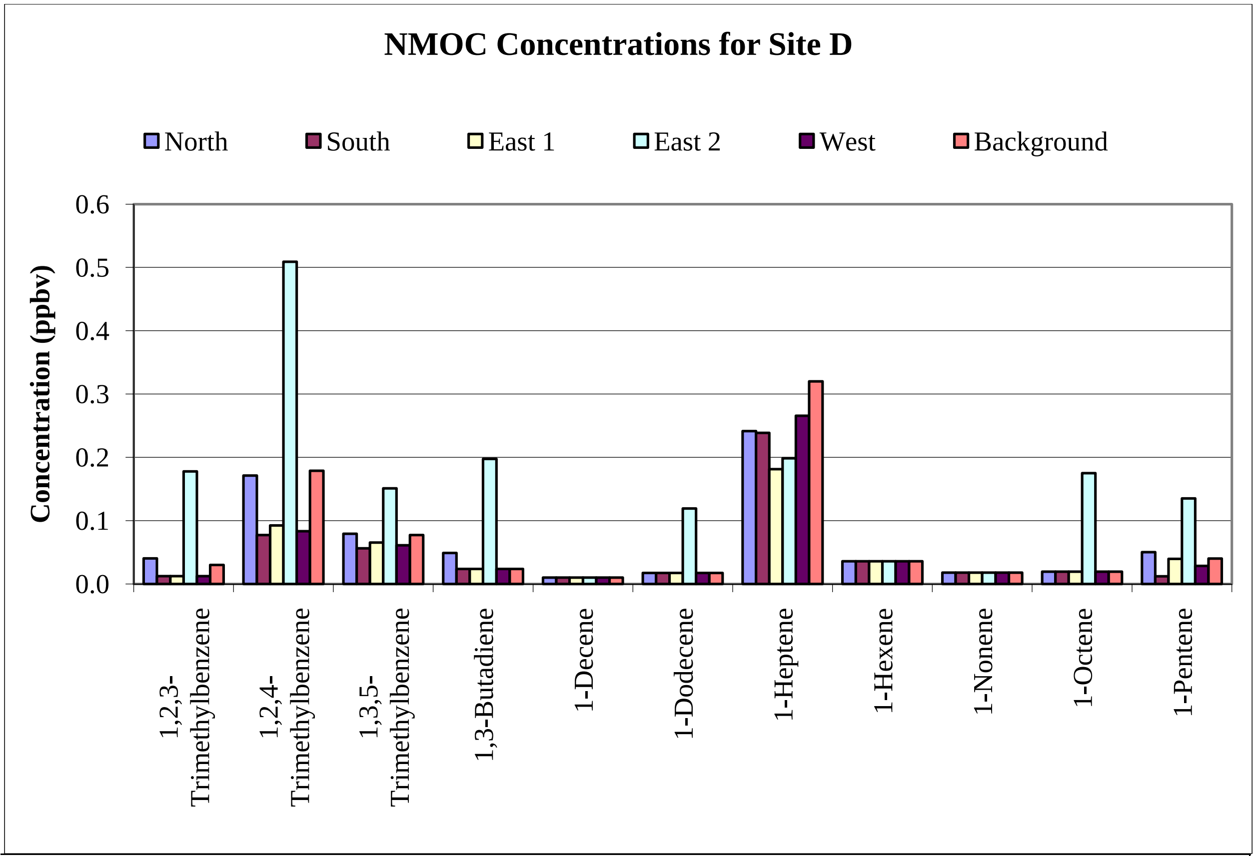

NMOC Concentrations for Site C
North 1
North 2
South
East
West
Background
Concentration (ppbC)
10,000
8,000
6,000
4,000
2,000
0
2,210
2,160
1,060
649
8,920
448
155
146
164
60
432
66
2,360
2,310
1,220
709
9,350
513
SNMOC (Sum of Knowns)
Sum of Unknowns
TNMOC

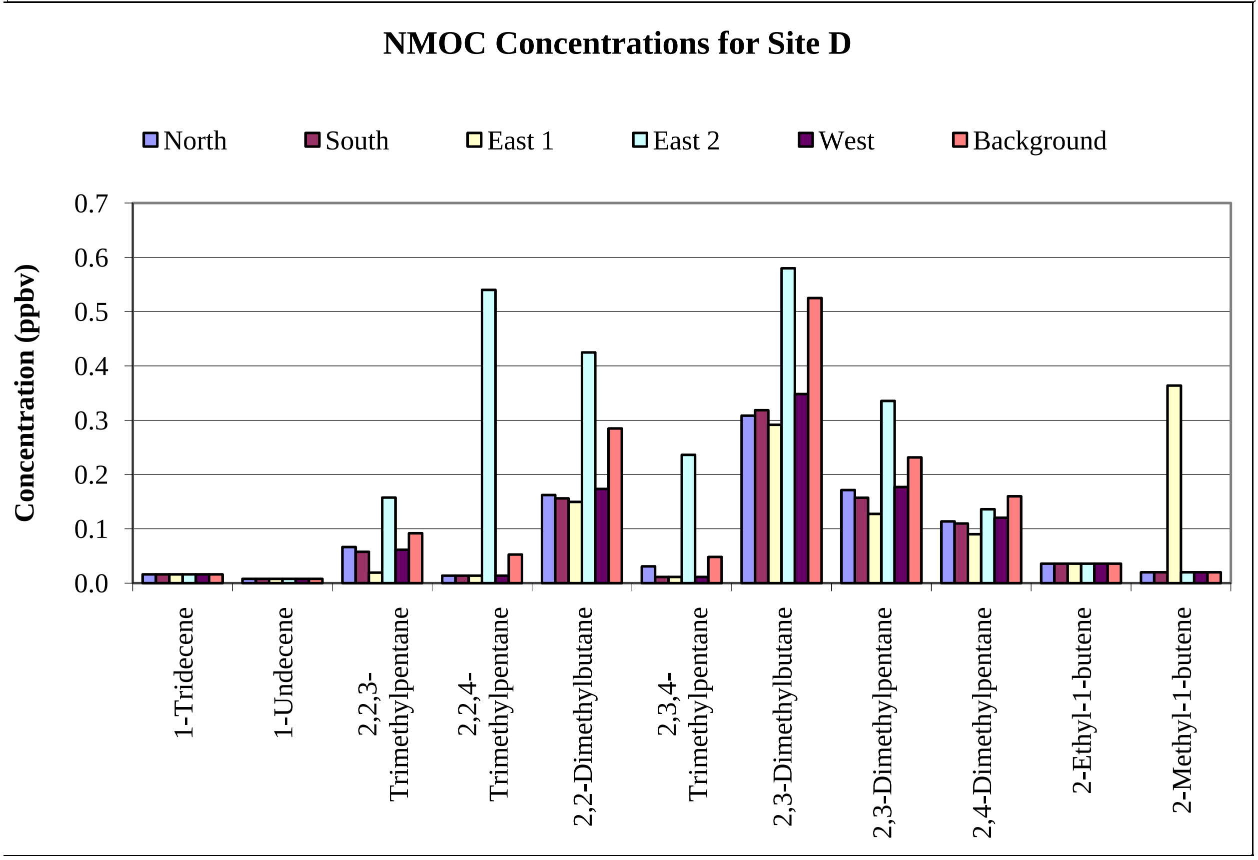
APPENDIX D – SITE D NMOC DATA AND GRAPHS

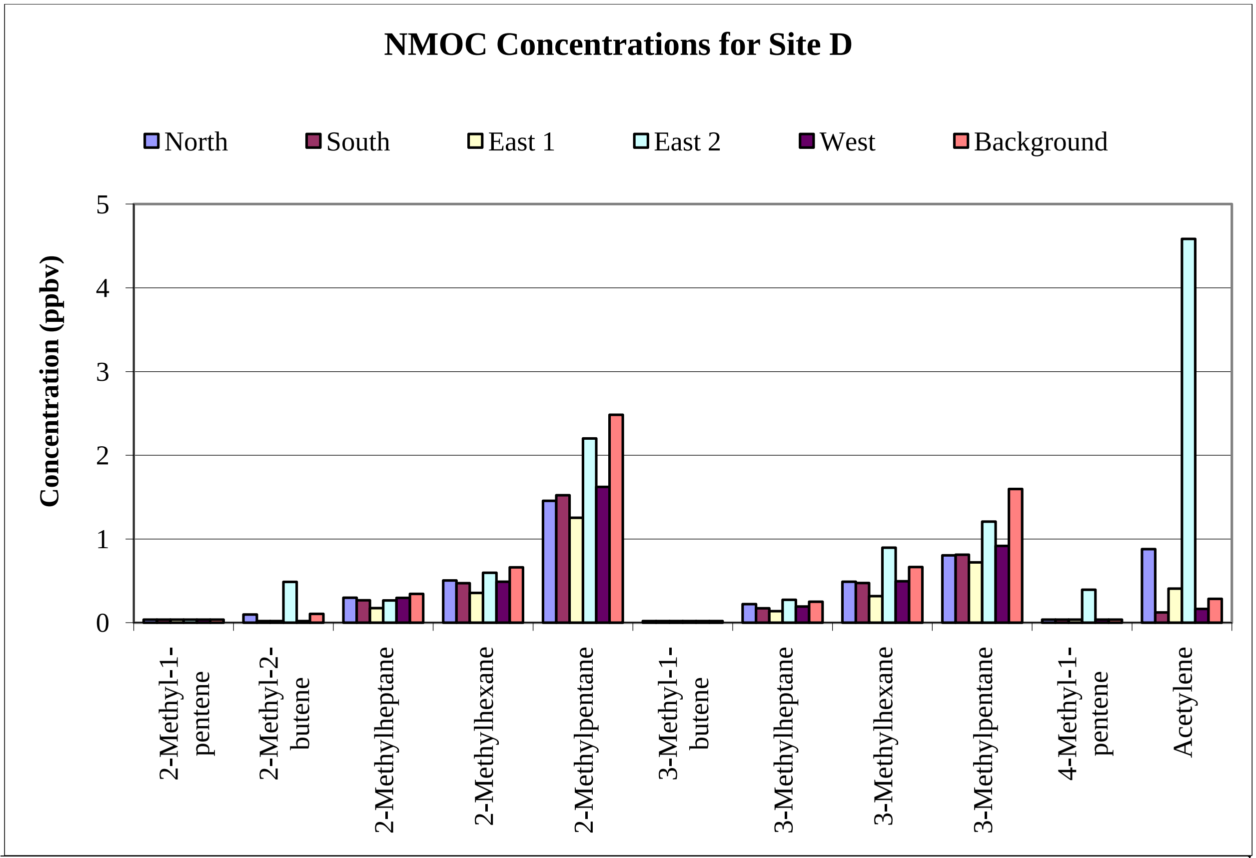
*****NOTE – All table and graph values represent 26 hour sampling periods.***

ANALYTE	Results						DL	UNITS
	North	**South**	**East 1**	**East 2**	**West**	**Background**		
1,2,3-Trimethylbenzene	0.040	0.012	0.012	0.178	0.012	0.030	0.024	ppbv
1,2,4-Trimethylbenzene	0.171	0.077	0.092	0.509	0.083	0.179	0.027	ppbv
1,3,5-Trimethylbenzene	0.079	0.056	0.065	0.151	0.061	0.077	0.022	ppbv
1,3-Butadiene	0.049	0.024	0.024	0.198	0.024	0.024	0.048	ppbv
1-Decene	0.010	0.010	0.010	0.010	0.010	0.010	0.020	ppbv
1-Dodecene	0.018	0.018	0.018	0.119	0.018	0.018	0.035	ppbv
1-Heptene	0.241	0.239	0.181	0.199	0.266	0.320	0.056	ppbv
1-Hexene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
1-Nonene	0.018	0.018	0.018	0.018	0.018	0.018	0.036	ppbv
1-Octene	0.019	0.019	0.019	0.175	0.019	0.019	0.039	ppbv
1-Pentene	0.050	0.012	0.040	0.135	0.029	0.040	0.024	ppbv
1-Tridecene	0.016	0.016	0.016	0.016	0.016	0.016	0.032	ppbv
1-Undecene	0.008	0.008	0.008	0.008	0.008	0.008	0.015	ppbv
2,2,3-Trimethylpentane	0.067	0.058	0.019	0.158	0.062	0.092	0.039	ppbv
2,2,4-Trimethylpentane	0.014	0.014	0.014	0.540	0.014	0.053	0.028	ppbv
2,2-Dimethylbutane	0.162	0.156	0.150	0.425	0.173	0.285	0.023	ppbv
2,3,4-Trimethylpentane	0.031	0.011	0.011	0.236	0.011	0.048	0.023	ppbv
2,3-Dimethylbutane	0.308	0.318	0.292	0.580	0.348	0.525	0.033	ppbv
2,3-Dimethylpentane	0.171	0.157	0.127	0.336	0.177	0.231	0.056	ppbv
2,4-Dimethylpentane	0.114	0.110	0.090	0.136	0.120	0.160	0.034	ppbv
2-Ethyl-1-butene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
2-Methyl-1-butene	0.020	0.020	0.364	0.020	0.020	0.020	0.040	ppbv
2-Methyl-1-pentene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
2-Methyl-2-butene	0.098	0.020	0.020	0.488	0.020	0.106	0.040	ppbv
2-Methylheptane	0.299	0.269	0.174	0.266	0.296	0.345	0.023	ppbv
2-Methylhexane	0.504	0.471	0.356	0.597	0.489	0.661	0.026	ppbv
2-Methylpentane	1.457	1.523	1.253	2.200	1.622	2.483	0.013	ppbv
3-Methyl-1-butene	0.020	0.020	0.020	0.020	0.020	0.020	0.040	ppbv
3-Methylheptane	0.223	0.173	0.138	0.274	0.194	0.250	0.025	ppbv
3-Methylhexane	0.489	0.474	0.317	0.897	0.494	0.664	0.033	ppbv
3-Methylpentane	0.805	0.812	0.720	1.207	0.917	1.597	0.030	ppbv
4-Methyl-1-pentene	0.036	0.036	0.036	0.393	0.036	0.036	0.072	ppbv
Acetylene	0.880	0.123	0.407	4.585	0.164	0.285	0.055	ppbv
a-Pinene	0.117	0.048	0.036	0.305	0.073	0.106	0.032	ppbv
Benzene	0.568	0.480	0.308	2.417	0.555	0.848	0.040	ppbv
b-Pinene	0.095	0.010	0.027	0.145	0.010	0.010	0.020	ppbv
cis-2-Butene	0.024	0.024	0.024	0.094	0.024	0.024	0.048	ppbv
cis-2-Hexene	0.036	0.036	0.036	0.113	0.036	0.036	0.072	ppbv
cis-2-Pentene	0.019	0.019	0.019	0.139	0.019	0.019	0.038	ppbv
Cyclohexane	1.297	1.060	0.895	8.750	1.137	2.200	0.037	ppbv
Cyclopentane	0.196	0.198	0.199	0.462	0.222	0.316	0.016	ppbv
Cyclopentene	0.091	0.074	0.084	0.082	0.094	0.170	0.040	ppbv
Ethane	47.5	46.6	40.1	31.9	47.3	58.0	0.045	ppbv

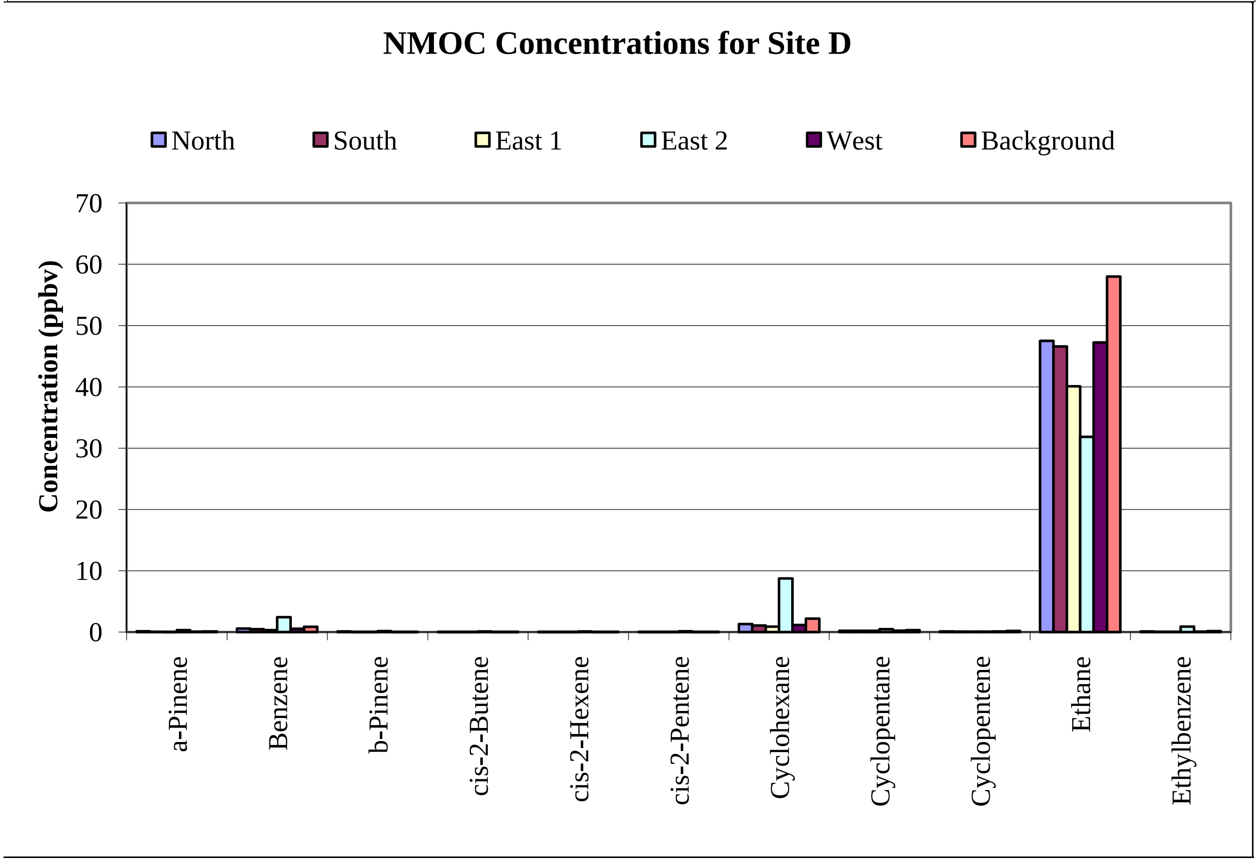
ANALYTE	Results						DL	UNITS
	North	South	East 1	East 2	West	Background		
Ethylbenzene	0.114	0.058	0.058	0.876	0.067	0.163	0.026	ppbv
Ethylene	1.120	0.480	0.525	4.450	0.785	0.620	0.035	ppbv
Isobutane	6.725	7.400	6.300	17.050	7.425	9.050	0.020	ppbv
Isobutene/1-Butene	1.888	1.590	1.153	0.018	1.915	3.375	0.035	ppbv
Isopentane	7.040	6.020	5.620	33.000	5.780	6.580	0.034	ppbv
Isoprene	0.248	0.236	0.224	0.472	0.240	0.308	0.040	ppbv
Isopropylbenzene	0.018	0.018	0.018	0.018	0.018	0.018	0.036	ppbv
m-Diethylbenzene	0.086	0.033	0.047	0.063	0.036	0.040	0.018	ppbv
Methylcyclohexane	2.243	2.186	1.571	1.413	2.371	2.886	0.021	ppbv
Methylcyclopentane	0.807	0.792	0.687	1.068	0.862	1.700	0.022	ppbv
m-Ethyltoluene	0.098	0.053	0.057	0.298	0.057	0.109	0.017	ppbv
m-Xylene/p-Xylene	0.610	0.443	0.395	2.375	0.520	0.799	0.039	ppbv
n-Butane	7.275	8.350	7.200	6.975	8.375	10.000	0.028	ppbv
n-Decane	0.339	0.188	0.140	2.990	0.167	0.301	0.020	ppbv
n-Dodecane	0.174	0.052	0.111	6.692	0.018	0.089	0.035	ppbv
n-Heptane	1.047	1.039	0.679	1.000	1.131	1.337	0.029	ppbv
n-Hexane	1.767	1.867	1.423	1.783	2.000	3.550	0.038	ppbv
n-Nonane	0.344	0.231	0.202	0.376	0.254	0.289	0.019	ppbv
n-Octane	0.700	0.630	0.449	0.533	0.706	0.801	0.030	ppbv
n-Pentane	3.160	3.400	3.100	32.600	3.660	5.020	0.020	ppbv
n-Propylbenzene	0.041	0.011	0.027	0.127	0.023	0.036	0.021	ppbv
n-Tridecane	0.016	0.016	0.046	0.702	0.016	0.016	0.032	ppbv
n-Undecane	0.416	0.187	0.146	8.682	0.123	0.340	0.015	ppbv
o-Ethyltoluene	0.091	0.039	0.046	0.216	0.041	0.063	0.032	ppbv
o-Xylene	0.139	0.089	0.078	0.850	0.094	0.190	0.021	ppbv
p-Diethylbenzene	0.025	0.006	0.020	0.075	0.006	0.015	0.012	ppbv
p-Ethyltoluene	0.065	0.062	0.038	0.190	0.041	0.073	0.029	ppbv
Propane	20.8	23.6	20.5	16.1	23.7	27.9	0.060	ppbv
Propylene	0.380	0.104	0.227	1.220	0.148	0.168	0.023	ppbv
Propyne	0.030	0.030	0.030	0.030	0.030	0.030	0.060	ppbv
Styrene	0.016	0.016	0.016	1.135	0.016	0.170	0.031	ppbv
Toluene	1.471	0.960	0.656	9.014	1.060	4.686	0.047	ppbv
trans-2-Butene	0.049	0.033	0.045	0.244	0.043	0.090	0.033	ppbv
trans-2-Hexene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
trans-2-Pentene	0.019	0.019	0.019	0.332	0.019	0.044	0.038	ppbv
SNMOC (Sum of Knowns)	409	392	336	1080	404	552		ppbC
Sum of Unknowns	86	73	51	419	63	115		ppbC
TNMOC	495	465	387	1500	467	667		ppbC


NMOC Concentrations for Site D
North
South
East 1
East 2
West
Background
Concentration (ppbv)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1,2,3-Trimethylbenzene
1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene
1,3-Butadiene
1-Decene
1-Dodecene
1-Heptene
1-Hexene
1-Nonene
1-Octene
1-Pentene

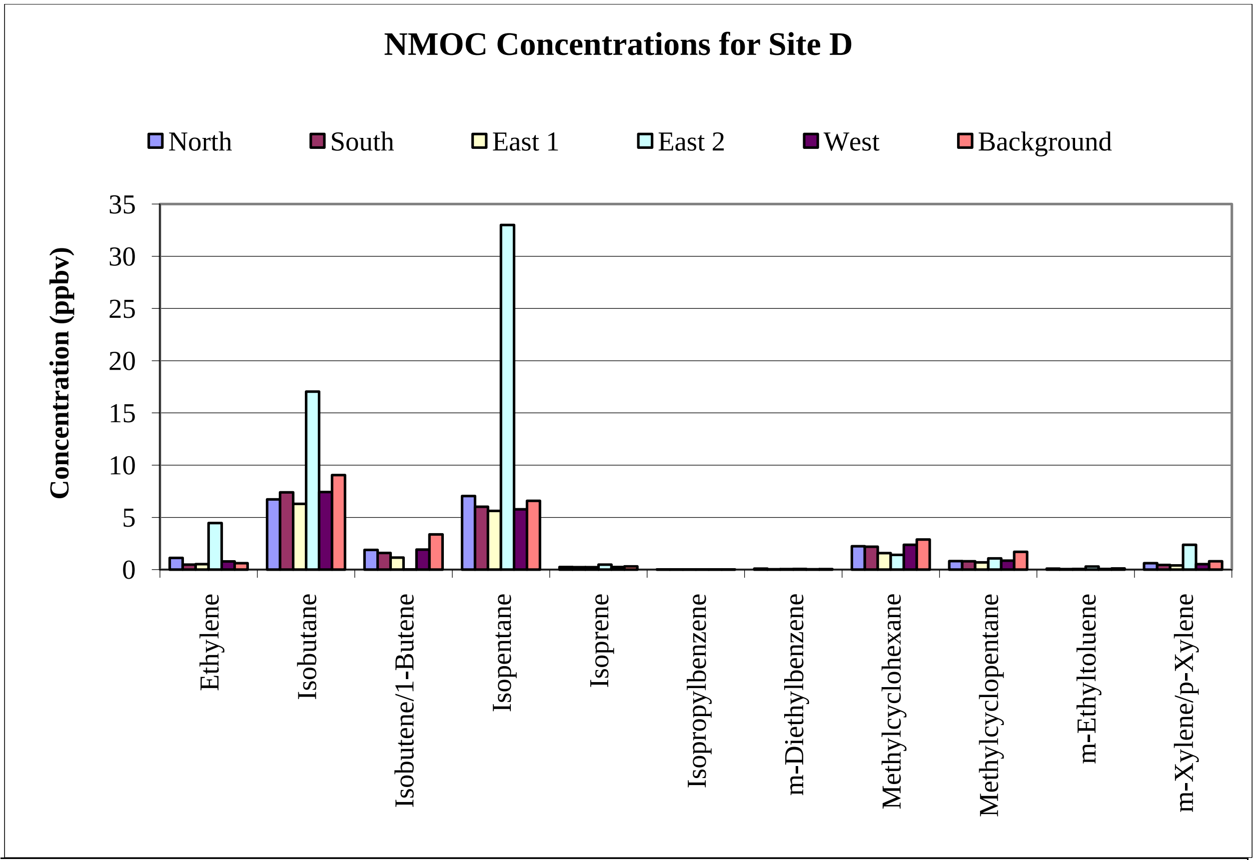

NMOC Concentrations for Site D
North
South
East 1
East 2
West
Background
Concentration (ppbv)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1-Tridecene
1-Undecene
2,2,3-Trimethylpentane
2,2,4-Trimethylpentane
2,2-Dimethylbutane
2,3,4-Trimethylpentane
2,3-Dimethylbutane
2,3-Dimethylpentane
2,4-Dimethylpentane
2-Ethyl-1-butene
2-Methyl-1-butene

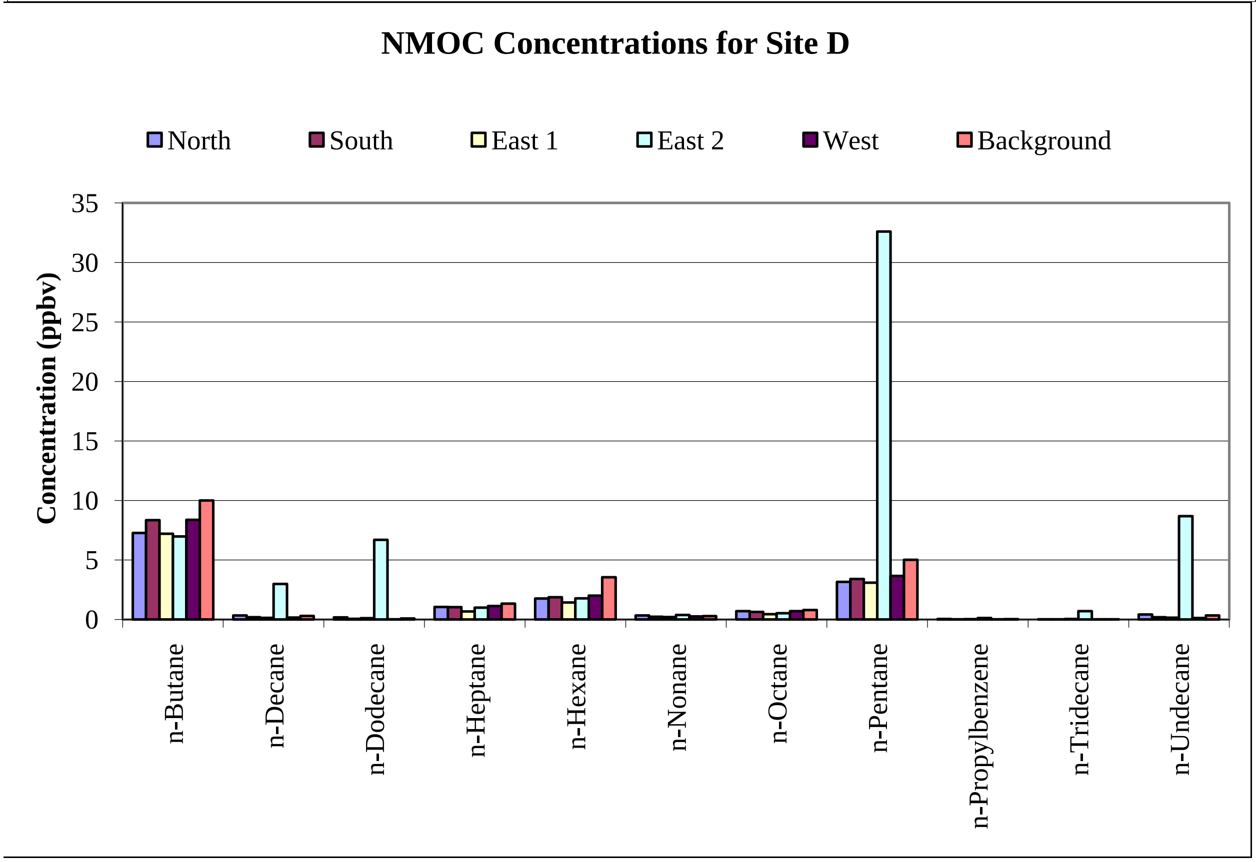


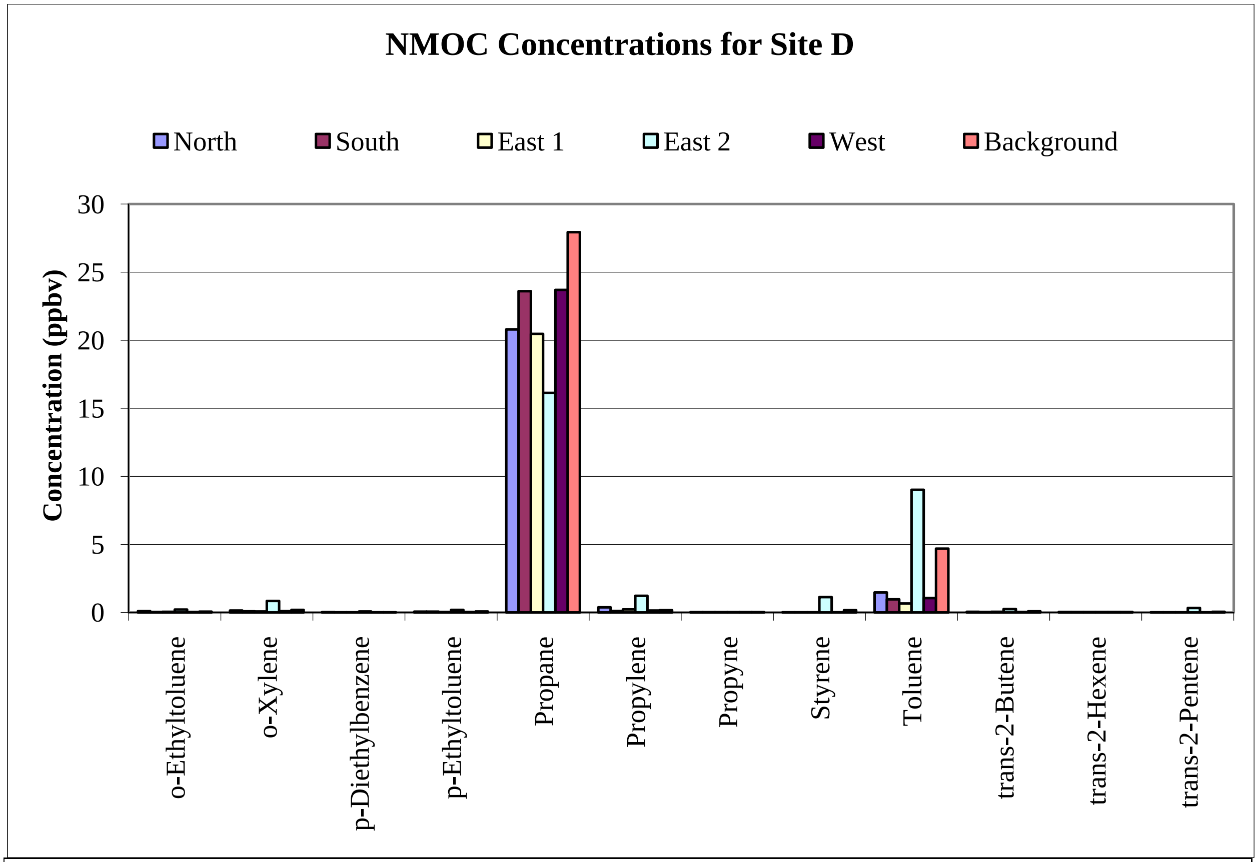
NMOC Concentrations for Site D

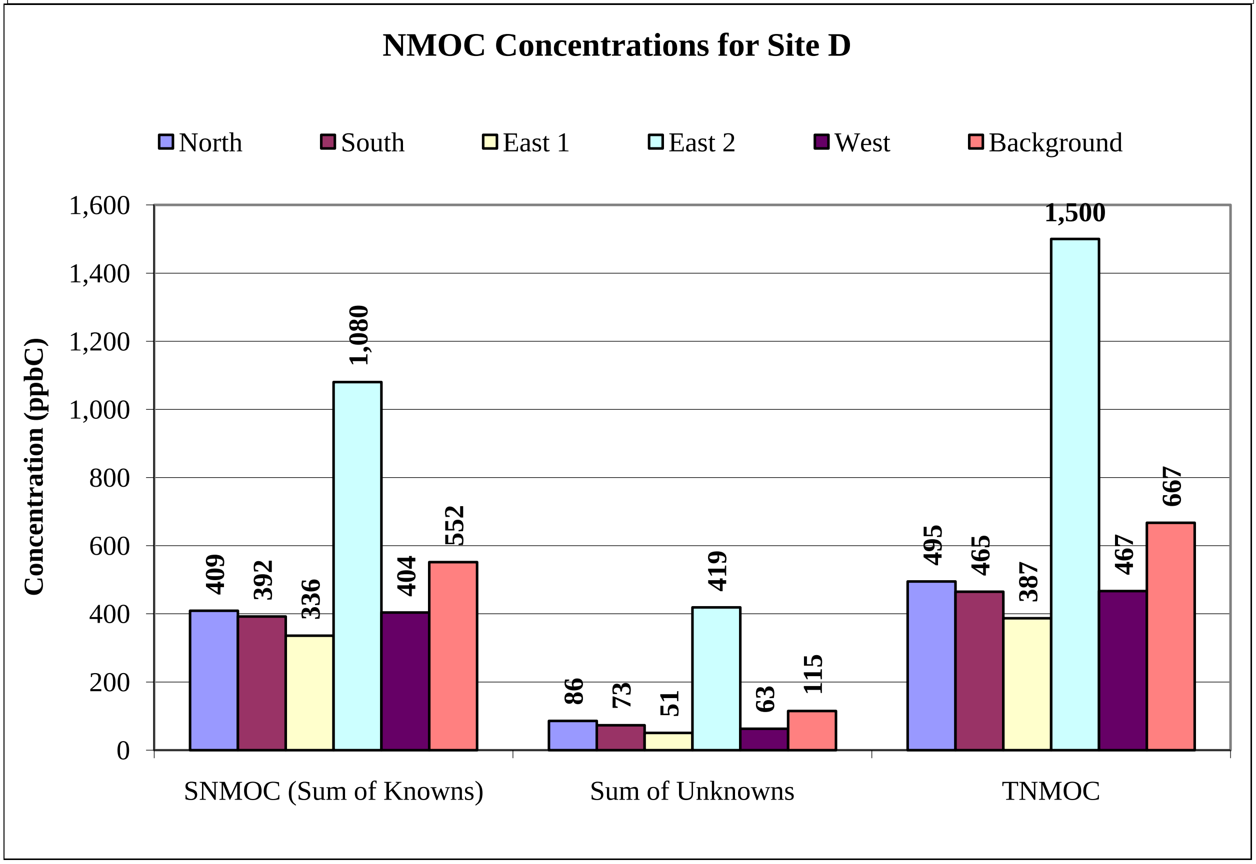


NMOC Concentrations for Site D


NMOC Concentrations for Site D


NMOC Concentrations for Site D


NMOC Concentrations for Site D
North
South
East 1
East 2
West
Background
Concentration (ppbv)
30
25
20
15
10
5
0
o-Ethyltoluene
o-Xylene
p-Diethylbenzene
p-Ethyltoluene
Propane
Propylene
Propyne
Styrene
Toluene
trans-2-Butene
trans-2-Hexene
trans-2-Pentene

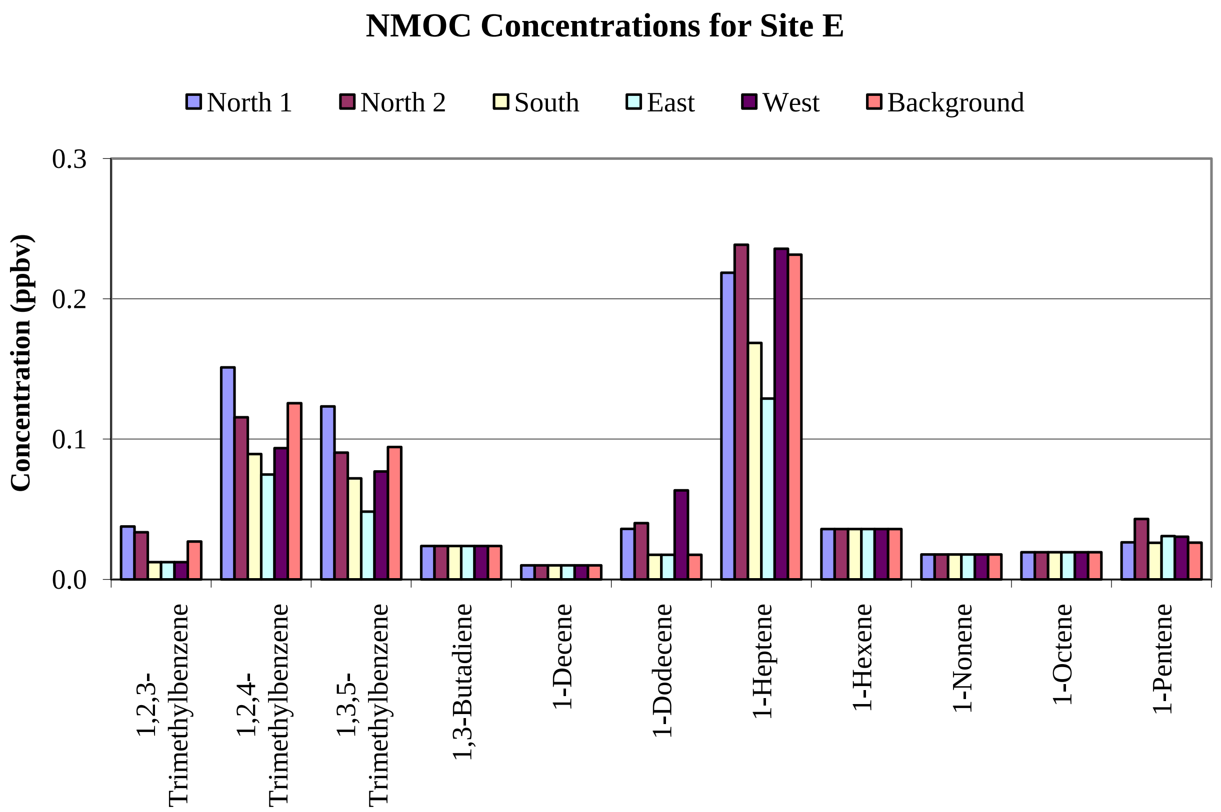

NMOC Concentrations for Site D
North
South
East 1
East 2
West
Background
Concentration (ppbC)
1,600
1,400
1,200
1,000
800
600
400
200
0
409
392
336
1,080
404
552
86
73
51
419
63
115
495
465
387
1,500
467
667
SNMOC (Sum of Knowns)
Sum of Unknowns
TNMOC

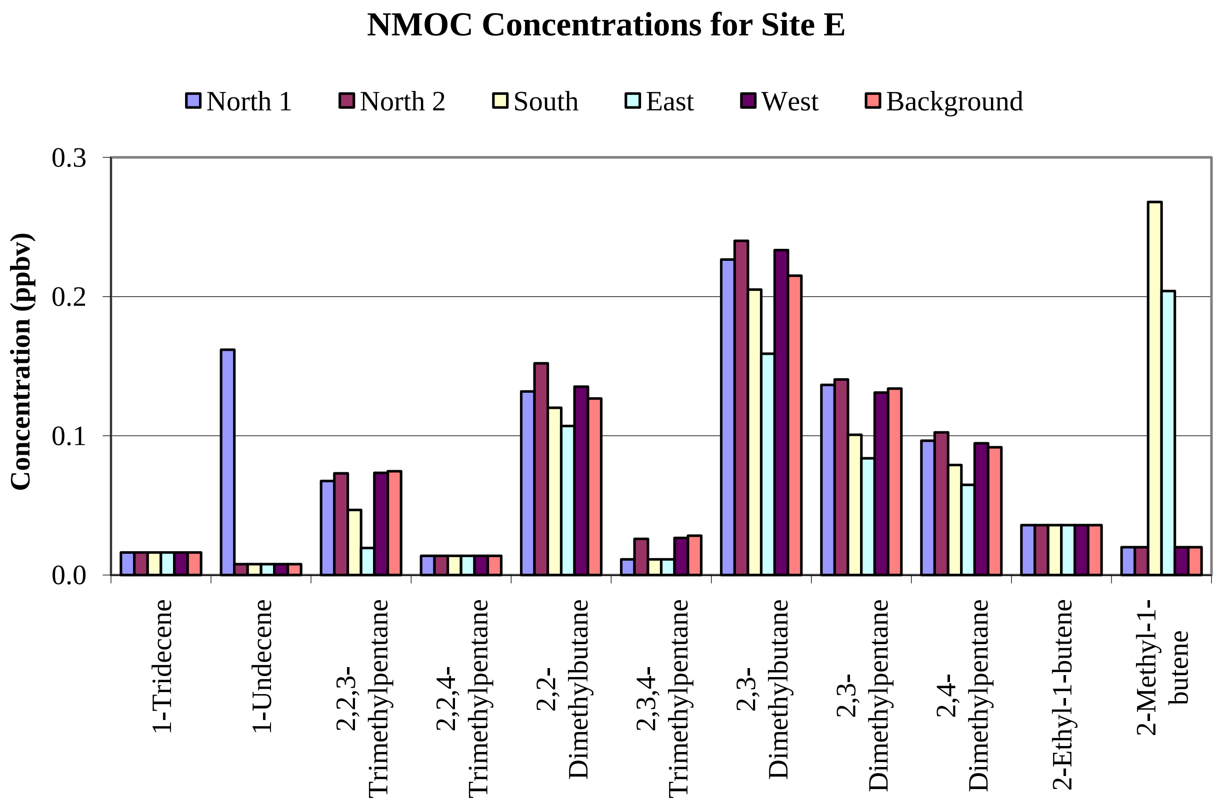
APPENDIX E – SITE E NMOC DATA AND GRAPHS

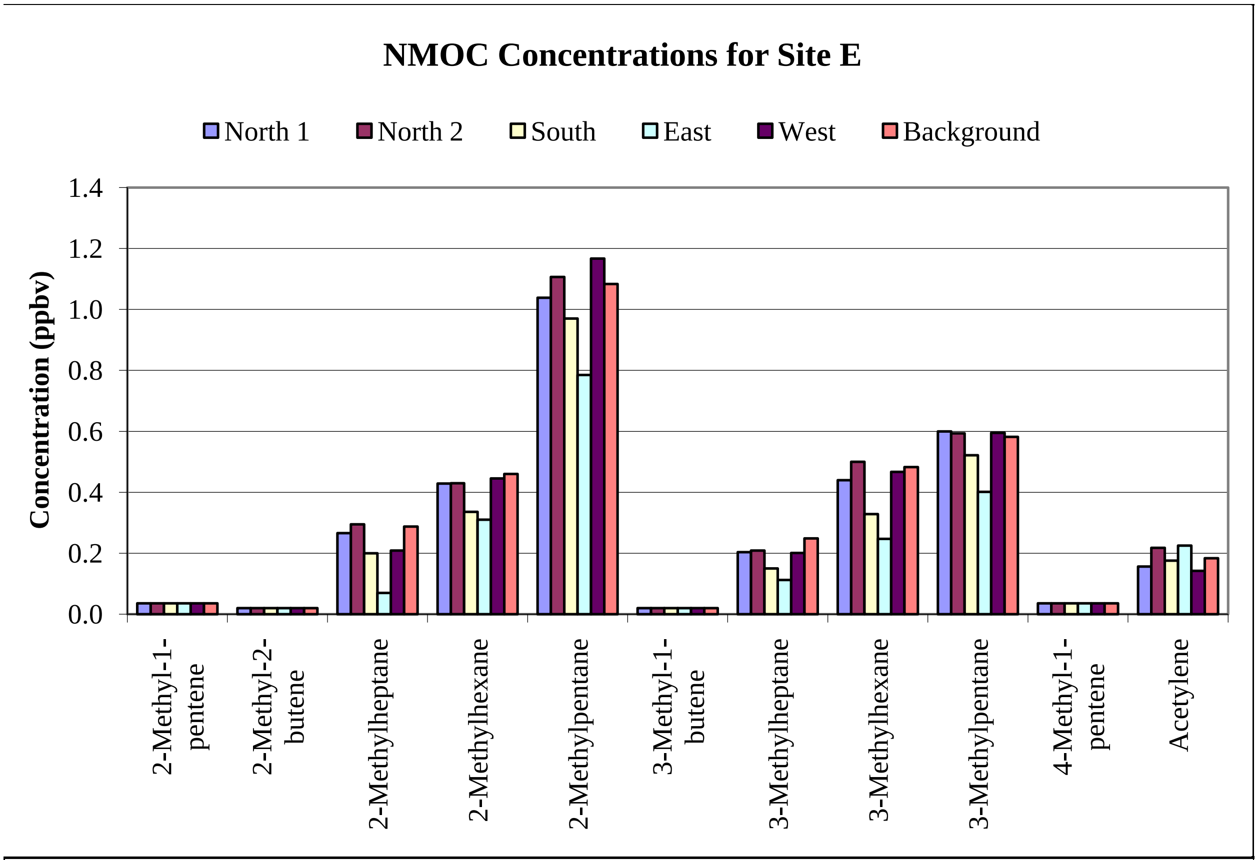
*****NOTE – All table and graph values represent 26 hour sampling periods.***

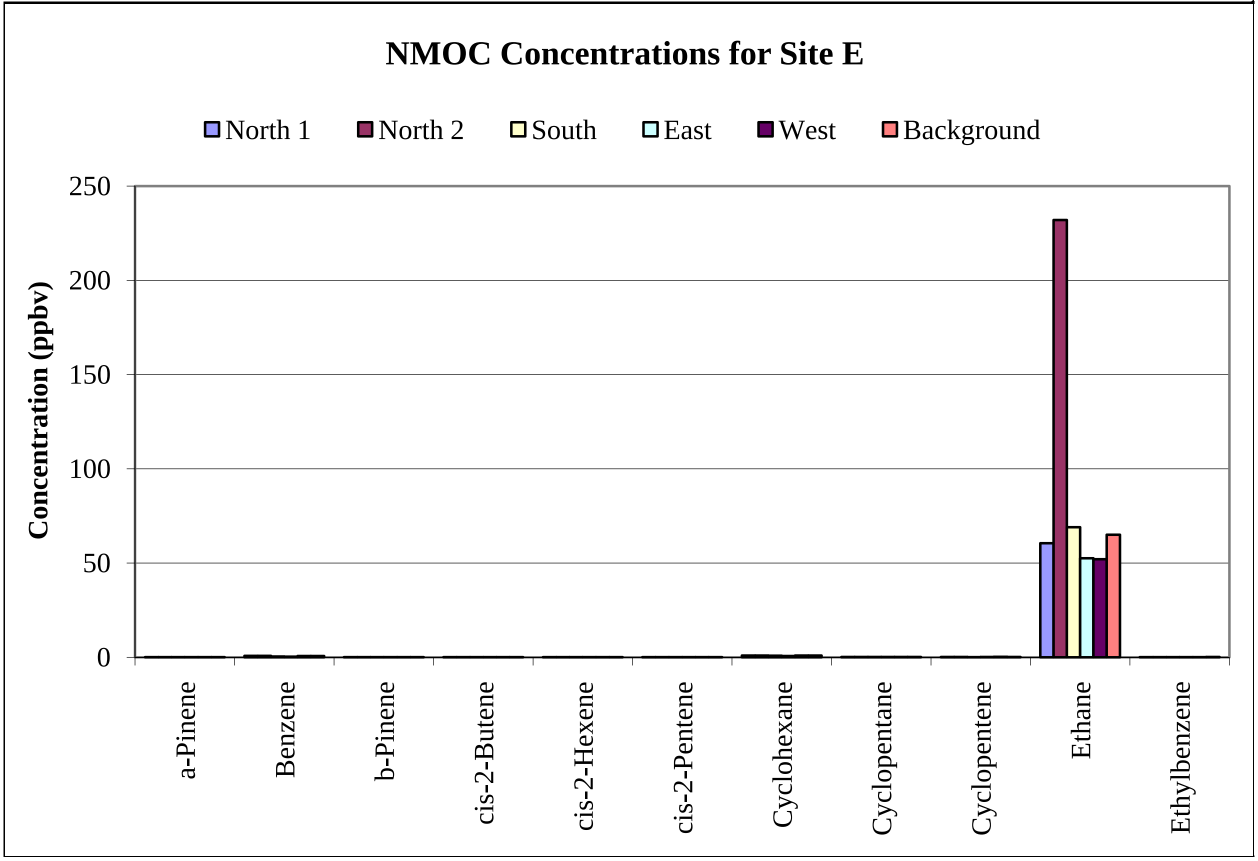
	Results							
ANALYTE	**North 1**	**North 2**	**South**	**East**	**West**	**Background**	**DL**	**UNITS**
1,2,3-Trimethylbenzene	0.038	0.034	0.012	0.012	0.012	0.027	0.024	ppbv
1,2,4-Trimethylbenzene	0.151	0.116	0.089	0.075	0.094	0.126	0.027	ppbv
1,3,5-Trimethylbenzene	0.123	0.090	0.072	0.048	0.077	0.094	0.022	ppbv
1,3-Butadiene	0.024	0.024	0.024	0.024	0.024	0.024	0.048	ppbv
1-Decene	0.010	0.010	0.010	0.010	0.010	0.010	0.020	ppbv
1-Dodecene	0.036	0.040	0.018	0.018	0.063	0.018	0.035	ppbv
1-Heptene	0.219	0.239	0.169	0.129	0.236	0.231	0.056	ppbv
1-Hexene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
1-Nonene	0.018	0.018	0.018	0.018	0.018	0.018	0.036	ppbv
1-Octene	0.019	0.019	0.019	0.019	0.019	0.019	0.039	ppbv
1-Pentene	0.026	0.043	0.026	0.031	0.030	0.026	0.024	ppbv
1-Tridecene	0.016	0.016	0.016	0.016	0.016	0.016	0.032	ppbv
1-Undecene	0.162	0.008	0.008	0.008	0.008	0.008	0.015	ppbv
2,2,3-Trimethylpentane	0.068	0.073	0.047	0.019	0.073	0.075	0.039	ppbv
2,2,4-Trimethylpentane	0.014	0.014	0.014	0.014	0.014	0.014	0.028	ppbv
2,2-Dimethylbutane	0.132	0.152	0.120	0.107	0.135	0.127	0.023	ppbv
2,3,4-Trimethylpentane	0.011	0.026	0.011	0.011	0.027	0.028	0.023	ppbv
2,3-Dimethylbutane	0.227	0.240	0.205	0.159	0.233	0.215	0.033	ppbv
2,3-Dimethylpentane	0.137	0.140	0.101	0.084	0.131	0.134	0.056	ppbv
2,4-Dimethylpentane	0.096	0.102	0.079	0.065	0.095	0.092	0.034	ppbv
2-Ethyl-1-butene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
2-Methyl-1-butene	0.020	0.020	0.268	0.204	0.020	0.020	0.040	ppbv
2-Methyl-1-pentene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
2-Methyl-2-butene	0.020	0.020	0.020	0.020	0.020	0.020	0.040	ppbv
2-Methylheptane	0.266	0.295	0.200	0.070	0.209	0.288	0.023	ppbv
2-Methylhexane	0.429	0.430	0.336	0.310	0.446	0.460	0.026	ppbv
2-Methylpentane	1.038	1.107	0.970	0.785	1.167	1.083	0.013	ppbv
3-Methyl-1-butene	0.020	0.020	0.020	0.020	0.020	0.020	0.040	ppbv
3-Methylheptane	0.204	0.209	0.150	0.113	0.201	0.249	0.025	ppbv
3-Methylhexane	0.440	0.500	0.329	0.247	0.467	0.483	0.033	ppbv
3-Methylpentane	0.600	0.593	0.522	0.402	0.595	0.582	0.030	ppbv
4-Methyl-1-pentene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
Acetylene	0.157	0.218	0.176	0.225	0.143	0.184	0.055	ppbv
a-Pinene	0.073	0.057	0.055	0.046	0.072	0.079	0.032	ppbv
Benzene	0.707	0.692	0.403	0.310	0.597	0.597	0.040	ppbv
b-Pinene	0.010	0.010	0.010	0.010	0.069	0.067	0.020	ppbv
cis-2-Butene	0.024	0.024	0.024	0.024	0.024	0.024	0.048	ppbv
cis-2-Hexene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
cis-2-Pentene	0.019	0.019	0.019	0.019	0.019	0.019	0.038	ppbv
Cyclohexane	0.892	0.918	0.773	0.653	0.887	0.853	0.037	ppbv
Cyclopentane	0.140	0.149	0.142	0.116	0.143	0.128	0.016	ppbv
Cyclopentene	0.086	0.144	0.063	0.096	0.234	0.136	0.040	ppbv
Ethane	60.5	232.0	69.0	52.5	52.0	65.0	0.045	ppbv

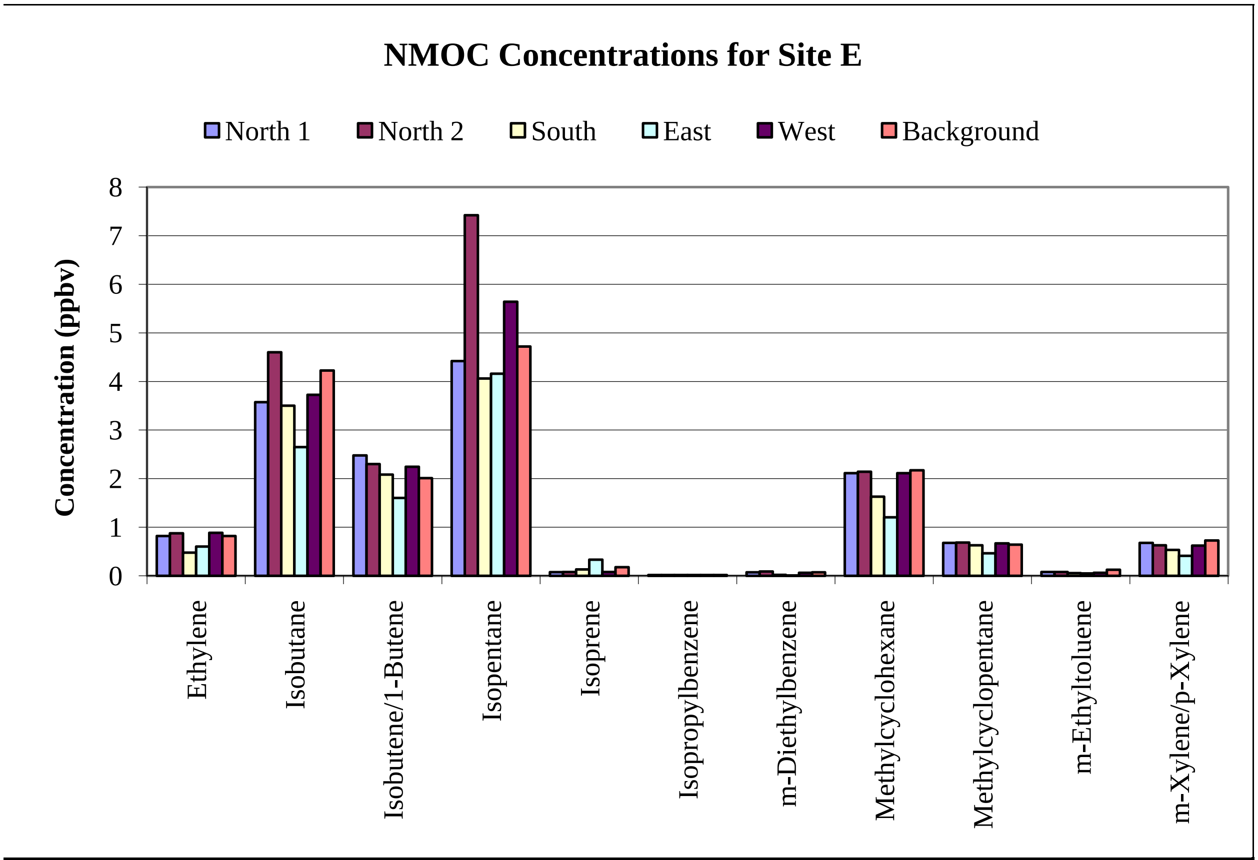
	Results							
ANALYTE	**North 1**	**North 2**	**South**	**East**	**West**	**Background**	**DL**	**UNITS**
Ethylbenzene	0.079	0.079	0.075	0.062	0.076	0.095	0.026	ppbv
Ethylene	0.820	0.875	0.479	0.605	0.885	0.820	0.035	ppbv
Isobutane	3.575	4.600	3.500	2.650	3.725	4.225	0.020	ppbv
Isobutene/1-Butene	2.480	2.303	2.083	1.603	2.245	2.010	0.035	ppbv
Isopentane	4.420	7.420	4.060	4.160	5.640	4.720	0.034	ppbv
Isoprene	0.078	0.082	0.132	0.334	0.079	0.178	0.040	ppbv
Isopropylbenzene	0.018	0.018	0.018	0.018	0.018	0.018	0.036	ppbv
m-Diethylbenzene	0.075	0.092	0.023	0.009	0.063	0.075	0.018	ppbv
Methylcyclohexane	2.114	2.143	1.629	1.204	2.114	2.171	0.021	ppbv
Methylcyclopentane	0.678	0.687	0.630	0.465	0.668	0.643	0.022	ppbv
m-Ethyltoluene	0.081	0.081	0.056	0.051	0.064	0.128	0.017	ppbv
m-Xylene/p-Xylene	0.679	0.629	0.535	0.411	0.623	0.728	0.039	ppbv
n-Butane	3.675	4.900	3.625	2.800	3.700	4.000	0.028	ppbv
n-Decane	0.380	0.406	0.262	0.292	0.260	0.311	0.020	ppbv
n-Dodecane	0.185	0.125	0.262	0.463	0.060	0.072	0.035	ppbv
n-Heptane	0.871	0.944	0.673	0.497	0.893	0.910	0.029	ppbv
n-Hexane	1.308	1.337	1.140	0.818	1.288	1.288	0.038	ppbv
n-Nonane	0.344	0.349	0.252	0.191	0.320	0.382	0.019	ppbv
n-Octane	0.660	0.698	0.510	0.379	0.733	0.735	0.030	ppbv
n-Pentane	1.830	2.020	1.878	1.416	1.908	1.936	0.020	ppbv
n-Propylbenzene	0.031	0.028	0.011	0.023	0.025	0.029	0.021	ppbv
n-Tridecane	0.047	0.016	0.084	0.104	0.016	0.016	0.032	ppbv
n-Undecane	0.439	0.495	0.363	0.646	0.246	0.297	0.015	ppbv
o-Ethyltoluene	0.077	0.078	0.059	0.016	0.052	0.061	0.032	ppbv
o-Xylene	0.120	0.118	0.091	0.075	0.108	0.134	0.021	ppbv
p-Diethylbenzene	0.027	0.023	0.006	0.017	0.013	0.018	0.012	ppbv
p-Ethyltoluene	0.154	0.063	0.034	0.014	0.042	0.050	0.029	ppbv
Propane	14.4	31.5	15.3	11.8	14.2	16.2	0.060	ppbv
Propylene	0.123	0.292	0.150	0.168	0.192	0.153	0.023	ppbv
Propyne	0.030	0.030	0.030	0.030	0.030	0.030	0.060	ppbv
Styrene	0.016	0.016	0.016	0.016	0.016	0.016	0.031	ppbv
Toluene	1.219	1.221	0.930	0.720	1.173	1.147	0.047	ppbv
trans-2-Butene	0.016	0.050	0.035	0.058	0.052	0.063	0.033	ppbv
trans-2-Hexene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
trans-2-Pentene	0.019	0.019	0.019	0.019	0.019	0.019	0.038	ppbv
SNMOC (Sum of Knowns)	353	772	344	280	333	367		ppbC
Sum of Unknowns	109	90	67	64	92	93		ppbC
TNMOC	461	862	411	344	425	460		ppbC

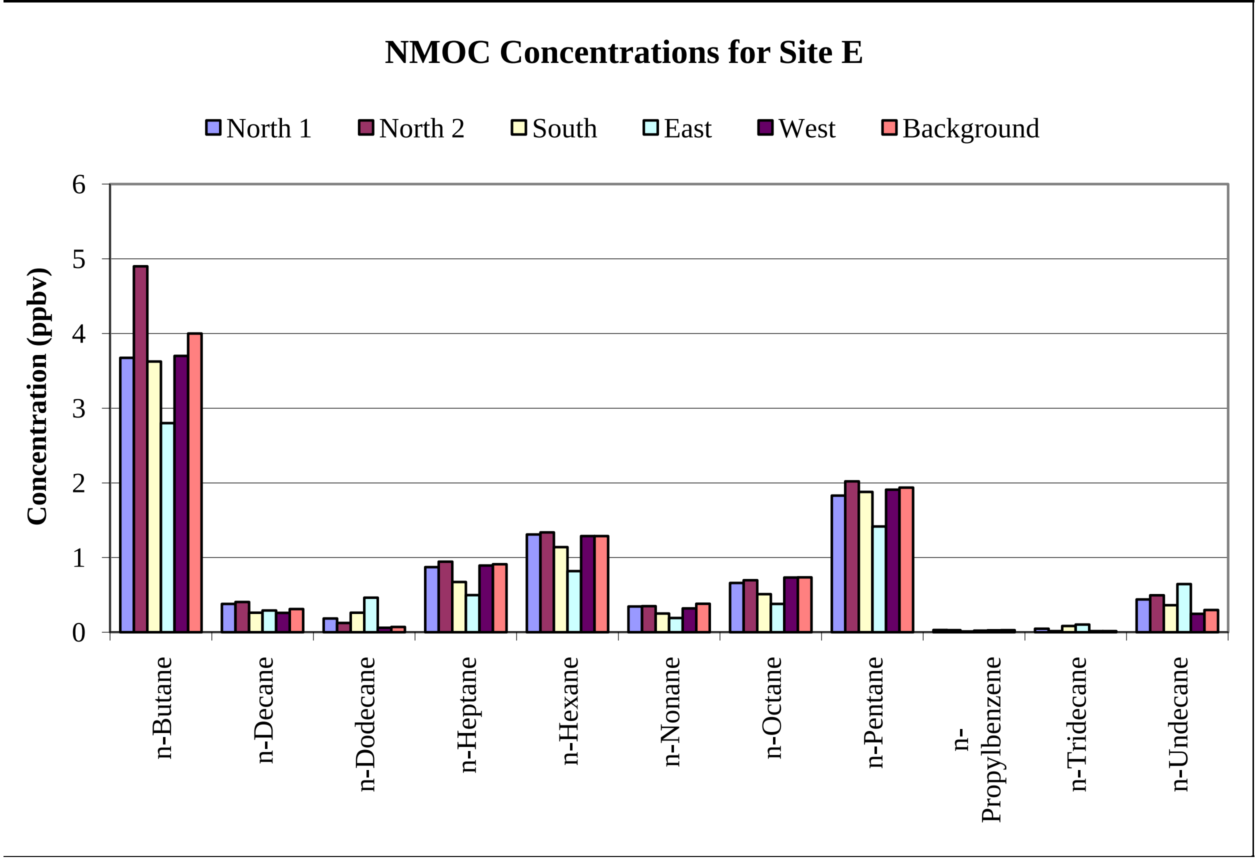

NMOC Concentrations for Site E
North 1
North 2
South
East
West
Background
Concentration (ppbv)
0.3
0.2
0.1
0.0
1,2,3-Trimethylbenzene
1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene
1,3-Butadiene
1-Decene
1-Dodecene
1-Heptene
1-Hexene
1-Nonene
1-Octene
1-Pentene

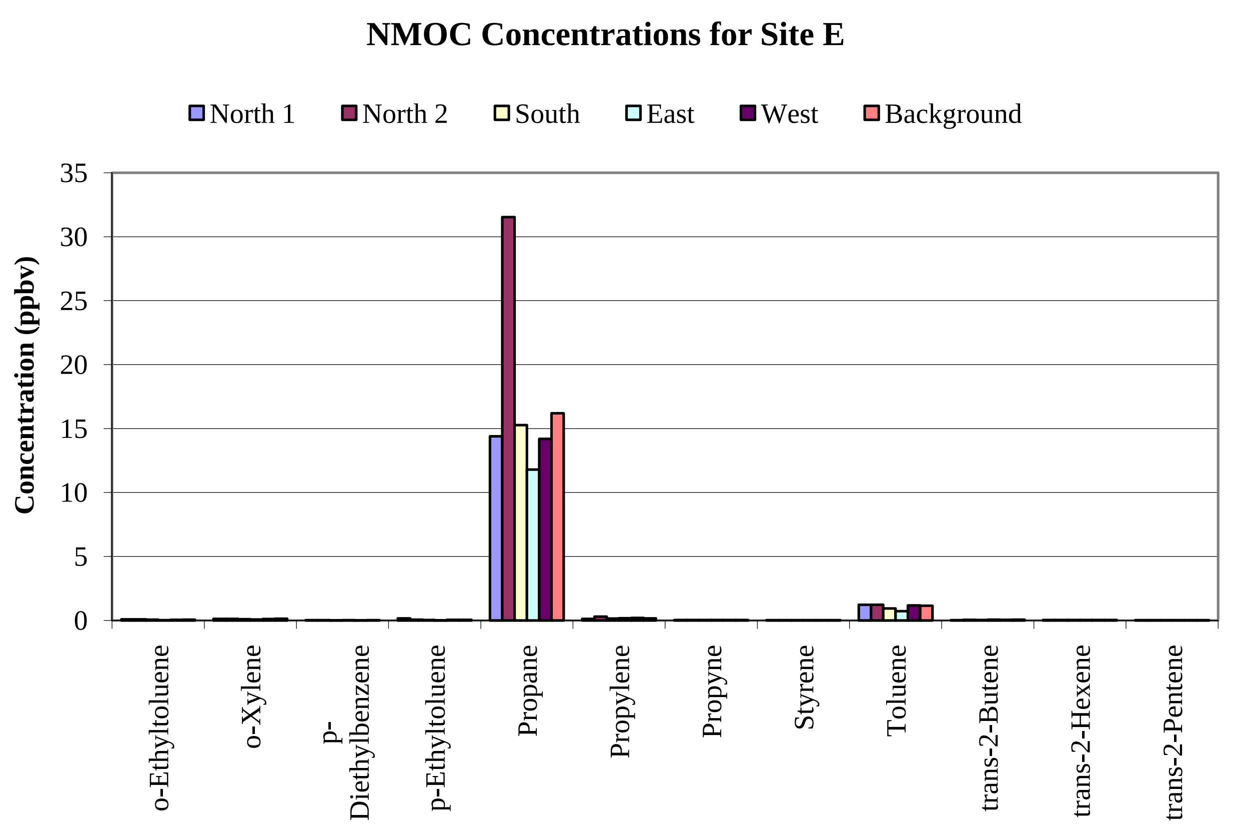

NMOC Concentrations for Site E
North 1
North 2
South
East
West
Background
Concentration (ppbv)
0.3
0.2
0.1
0.0
1-Tridecene
1-Undecene
2,2,3-Trimethylpentane
2,2,4-Trimethylpentane
2,2-Dimethylbutane
2,3,4-Trimethylpentane
2,3-Dimethylbutane
2,3-Dimethylpentane
2,4-Dimethylpentane
2-Ethyl-1-butene
2-Methyl-1-butene

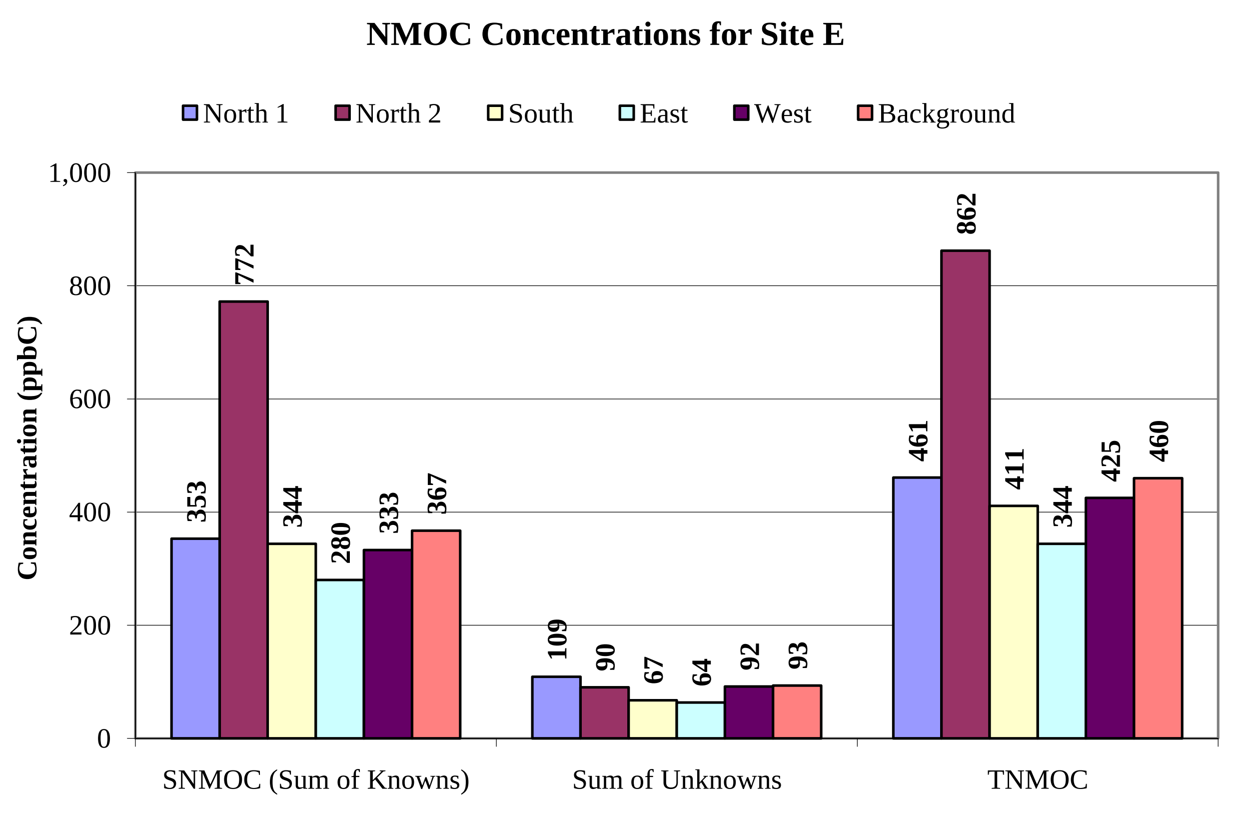

NMOC Concentrations for Site E
North 1
North 2
South
East
West
Background
Concentration (ppbv)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2-Methyl-1-pentene
2-Methyl-2-butene
2-Methylheptane
2-Methylhexane
2-Methylpentane
3-Methyl-1-butene
3-Methylheptane
3-Methylhexane
3-Methylpentane
4-Methyl-1-pentene
Acetylene


NMOC Concentrations for Site E
North 1
North 2
South
East
West
Background
Concentration (ppbv)
250
200
150
100
50
0
a-Pinene
Benzene
b-Pinene
cis-2-Butene
cis-2-Hexene
cis-2-Pentene
Cyclohexane
Cyclopentane
Cyclopentene
Ethane
Ethylbenzene


NMOC Concentrations for Site E
North 1
North 2
South
East
West
Background
Concentration (ppbv)
0
1
2
3
4
5
6
7
8
Ethylene
Isobutane
Isobutene/1-Butene
Isopentane
Isoprene
Isopropylbenzene
m-Diethylbenzene
Methylcyclohexane
Methylcyclopentane
m-Ethyltoluene
m-Xylene/p-Xylene


NMOC Concentrations for Site E
North 1
North 2
South
East
West
Background
Concentration (ppbv)
0
1
2
3
4
5
6
n-Butane
n-Decane
n-Dodecane
n-Heptane
n-Hexane
n-Nonane
n-Octane
n-Pentane
n-Propylbenzene
n-Tridecane
n-Undecane


NMOC Concentrations for Site E

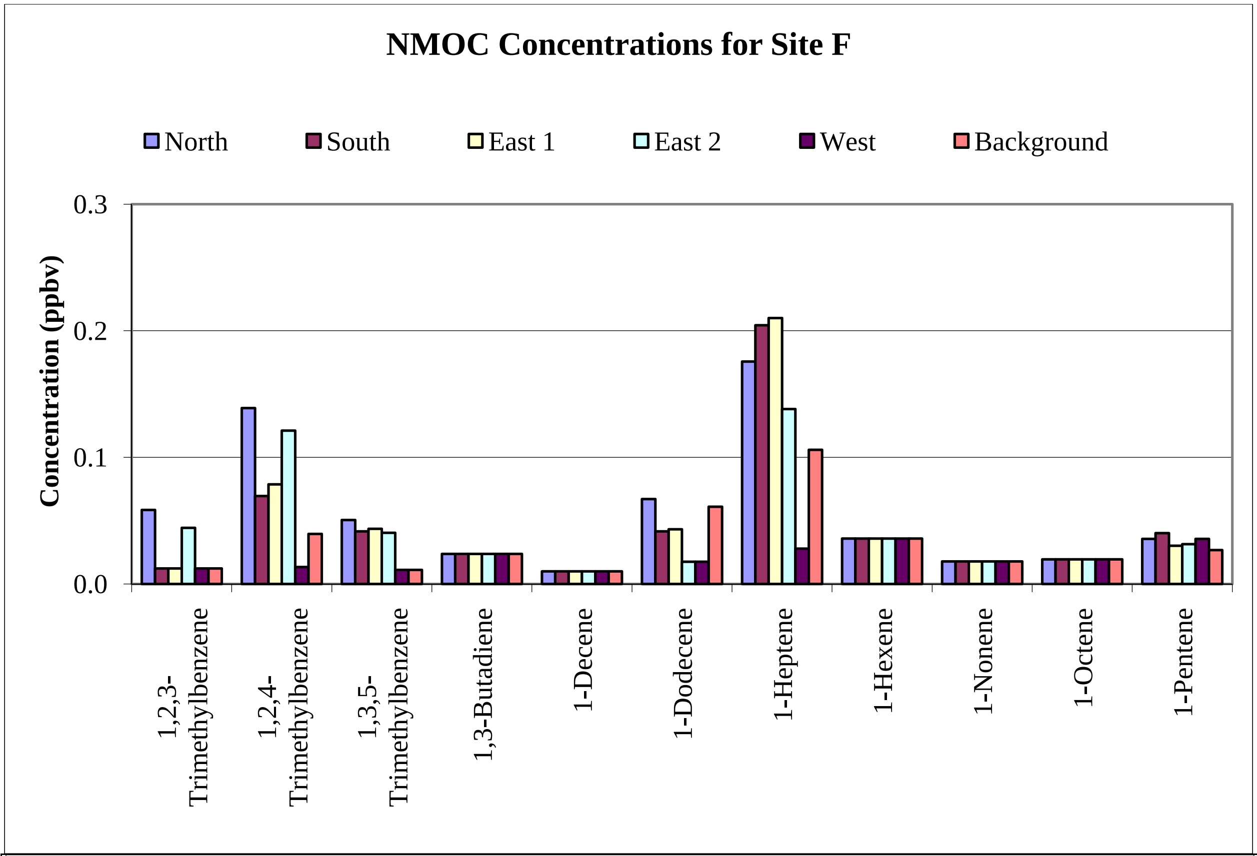

NMOC Concentrations for Site E

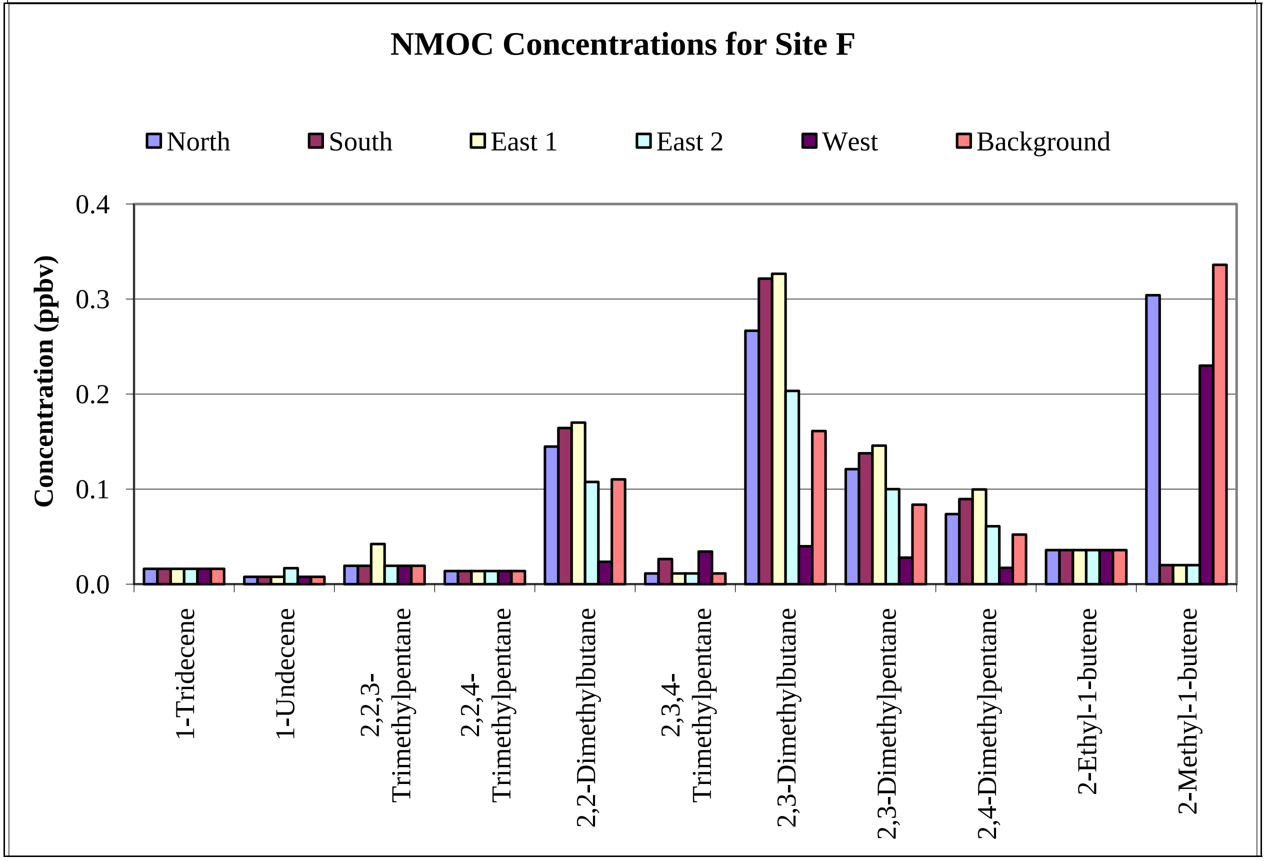
APPENDIX F – SITE F NMOC DATA AND GRAPHS

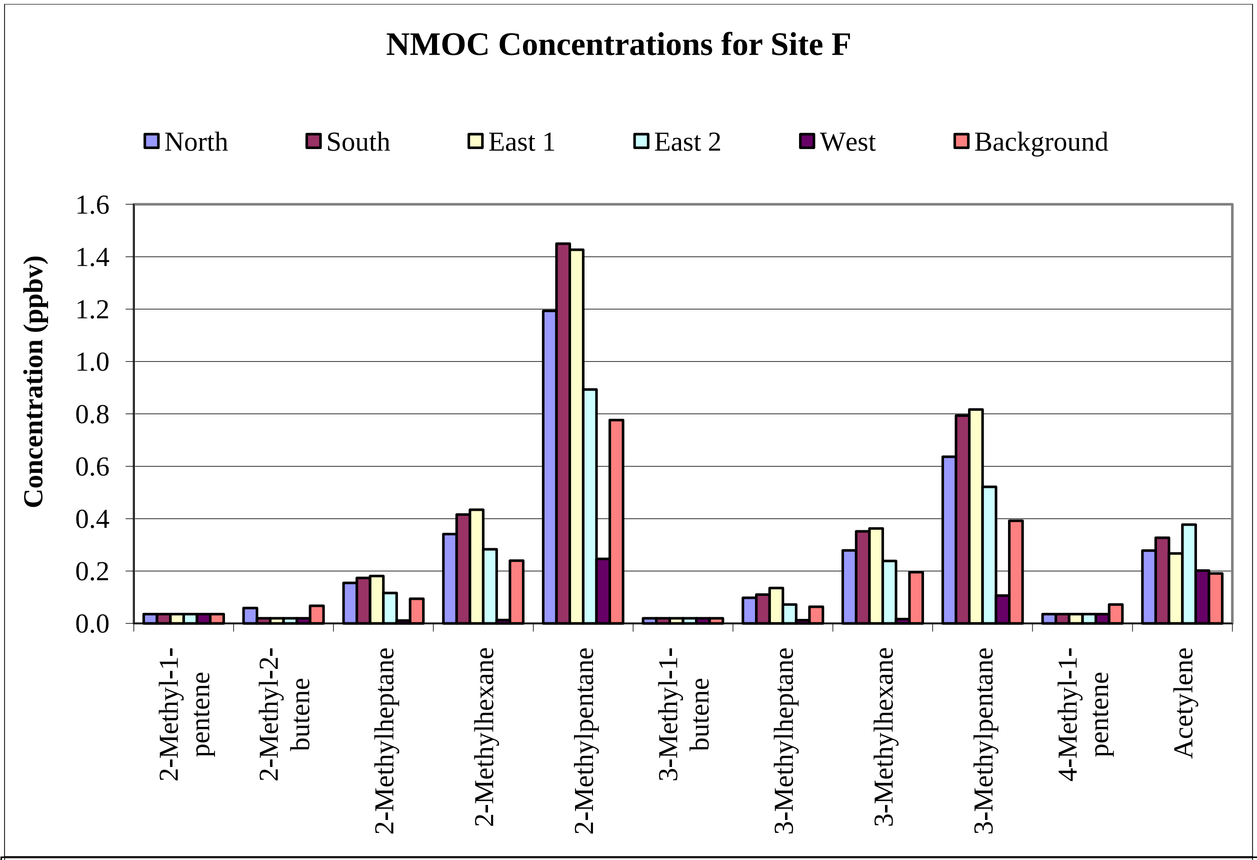
*****NOTE – All table and graph values represent 25 hour sampling periods.***

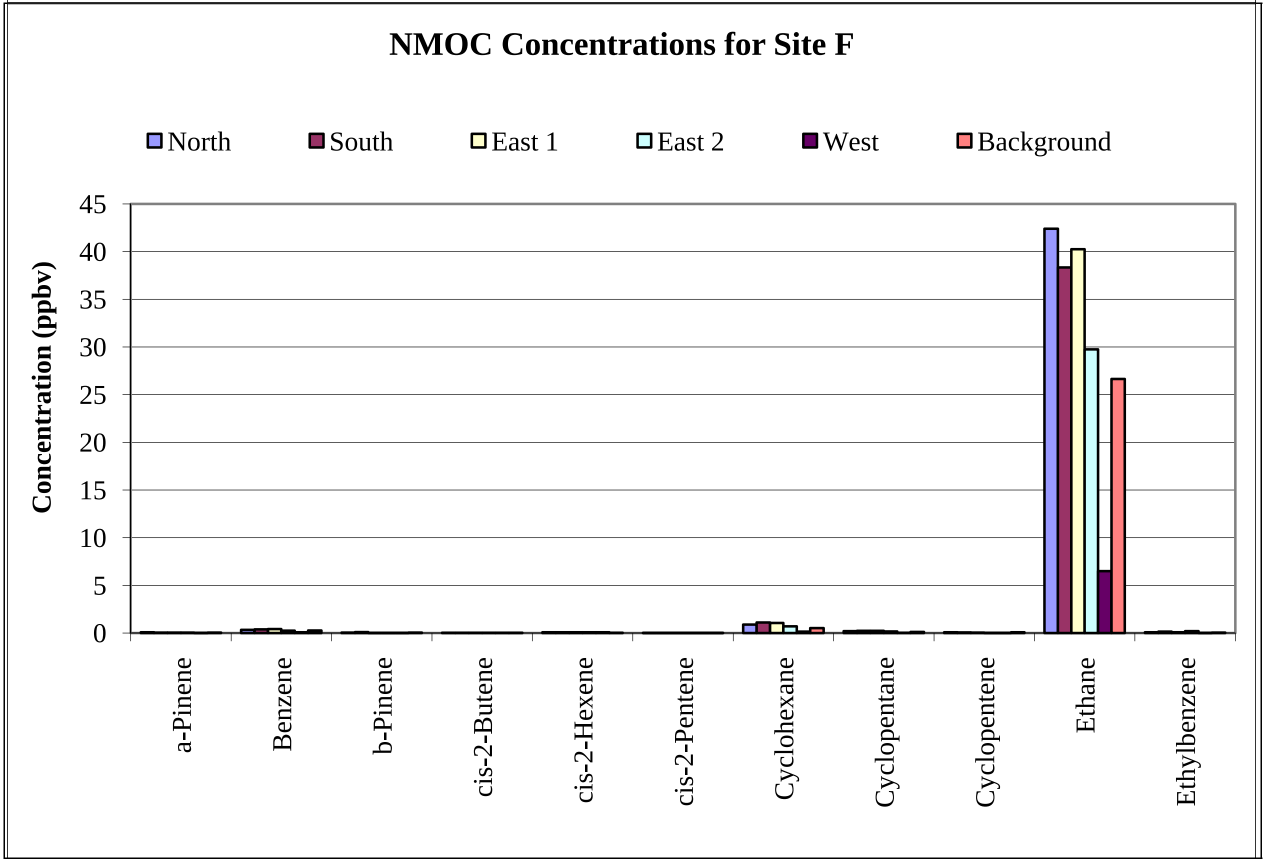
ANALYTE	Results						DL	UNITS
	North	**South**	**East 1**	**East 2**	**West**	**Background**		
1,2,3-Trimethylbenzene	0.058	0.012	0.012	0.044	0.012	0.012	0.024	ppbv
1,2,4-Trimethylbenzene	0.139	0.069	0.079	0.121	0.013	0.039	0.027	ppbv
1,3,5-Trimethylbenzene	0.050	0.042	0.044	0.040	0.011	0.011	0.022	ppbv
1,3-Butadiene	0.024	0.024	0.024	0.024	0.024	0.024	0.048	ppbv
1-Decene	0.010	0.010	0.010	0.010	0.010	0.010	0.020	ppbv
1-Dodecene	0.067	0.042	0.043	0.018	0.018	0.061	0.035	ppbv
1-Heptene	0.176	0.204	0.210	0.138	0.028	0.106	0.056	ppbv
1-Hexene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
1-Nonene	0.018	0.018	0.018	0.018	0.018	0.018	0.036	ppbv
1-Octene	0.019	0.019	0.019	0.019	0.019	0.019	0.039	ppbv
1-Pentene	0.036	0.040	0.030	0.031	0.036	0.027	0.024	ppbv
1-Tridecene	0.016	0.016	0.016	0.016	0.016	0.016	0.032	ppbv
1-Undecene	0.008	0.008	0.008	0.017	0.008	0.008	0.015	ppbv
2,2,3-Trimethylpentane	0.019	0.019	0.042	0.019	0.019	0.019	0.039	ppbv
2,2,4-Trimethylpentane	0.014	0.014	0.014	0.014	0.014	0.014	0.028	ppbv
2,2-Dimethylbutane	0.145	0.164	0.170	0.108	0.024	0.110	0.023	ppbv
2,3,4-Trimethylpentane	0.011	0.026	0.011	0.011	0.034	0.011	0.023	ppbv
2,3-Dimethylbutane	0.267	0.322	0.327	0.203	0.040	0.161	0.033	ppbv
2,3-Dimethylpentane	0.121	0.138	0.146	0.100	0.028	0.084	0.056	ppbv
2,4-Dimethylpentane	0.074	0.090	0.100	0.061	0.017	0.052	0.034	ppbv
2-Ethyl-1-butene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
2-Methyl-1-butene	0.304	0.020	0.020	0.020	0.230	0.336	0.040	ppbv
2-Methyl-1-pentene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
2-Methyl-2-butene	0.059	0.020	0.020	0.020	0.020	0.067	0.040	ppbv
2-Methylheptane	0.155	0.174	0.181	0.116	0.011	0.094	0.023	ppbv
2-Methylhexane	0.341	0.416	0.434	0.283	0.013	0.240	0.026	ppbv
2-Methylpentane	1.193	1.450	1.427	0.893	0.247	0.777	0.013	ppbv
3-Methyl-1-butene	0.020	0.020	0.020	0.020	0.020	0.020	0.040	ppbv
3-Methylheptane	0.098	0.110	0.135	0.072	0.013	0.064	0.025	ppbv
3-Methylhexane	0.279	0.351	0.363	0.239	0.016	0.196	0.033	ppbv
3-Methylpentane	0.637	0.793	0.817	0.522	0.107	0.392	0.030	ppbv
4-Methyl-1-pentene	0.036	0.036	0.036	0.036	0.036	0.073	0.072	ppbv
Acetylene	0.278	0.327	0.267	0.377	0.202	0.191	0.055	ppbv
a-Pinene	0.076	0.051	0.042	0.052	0.016	0.054	0.032	ppbv
Benzene	0.332	0.383	0.413	0.257	0.082	0.273	0.040	ppbv
b-Pinene	0.053	0.091	0.010	0.010	0.010	0.047	0.020	ppbv
cis-2-Butene	0.024	0.024	0.024	0.024	0.024	0.024	0.048	ppbv
cis-2-Hexene	0.078	0.083	0.078	0.083	0.082	0.036	0.072	ppbv
cis-2-Pentene	0.019	0.019	0.019	0.019	0.019	0.019	0.038	ppbv
Cyclohexane	0.890	1.110	1.060	0.695	0.151	0.520	0.037	ppbv
Cyclopentane	0.192	0.236	0.226	0.162	0.031	0.115	0.016	ppbv
Cyclopentene	0.081	0.071	0.049	0.020	0.020	0.082	0.040	ppbv
Ethane	42.4	38.4	40.3	29.8	6.5	26.7	0.045	ppbv

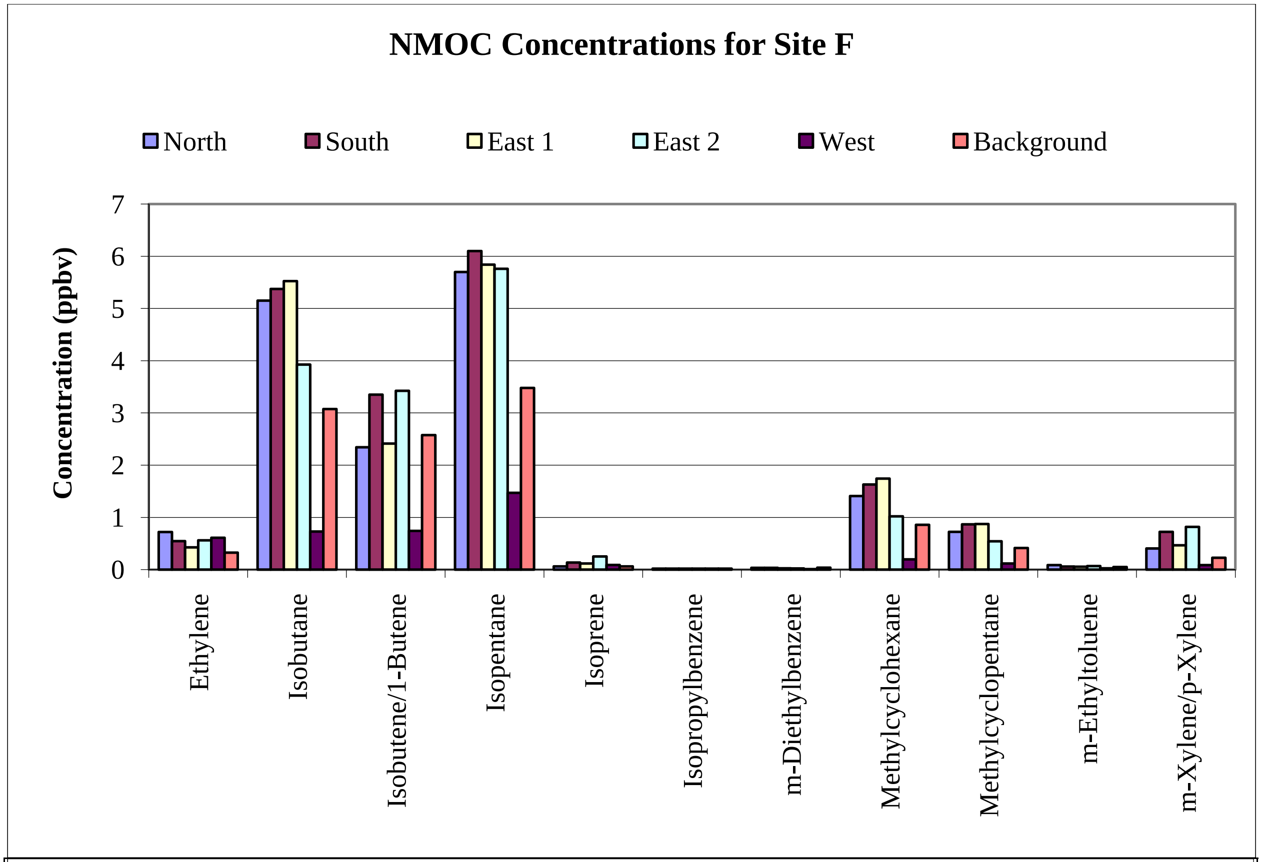
	Results							
ANALYTE	**North**	**South**	**East 1**	**East 2**	**West**	**Background**	**DL**	**UNITS**
Ethylbenzene	0.082	0.148	0.075	0.201	0.013	0.045	0.026	ppbv
Ethylene	0.720	0.545	0.426	0.560	0.610	0.325	0.035	ppbv
Isobutane	5.150	5.375	5.525	3.925	0.730	3.075	0.020	ppbv
Isobutene/1-Butene	2.343	3.350	2.413	3.425	0.740	2.575	0.035	ppbv
Isopentane	5.700	6.100	5.840	5.760	1.470	3.480	0.034	ppbv
Isoprene	0.061	0.135	0.118	0.252	0.089	0.060	0.040	ppbv
Isopropylbenzene	0.018	0.018	0.018	0.018	0.018	0.018	0.036	ppbv
m-Diethylbenzene	0.034	0.034	0.025	0.020	0.009	0.037	0.018	ppbv
Methylcyclohexane	1.409	1.629	1.743	1.019	0.197	0.857	0.021	ppbv
Methylcyclopentane	0.723	0.867	0.873	0.543	0.116	0.415	0.022	ppbv
m-Ethyltoluene	0.085	0.058	0.055	0.068	0.024	0.050	0.017	ppbv
m-Xylene/p-Xylene	0.405	0.724	0.466	0.818	0.086	0.228	0.039	ppbv
n-Butane	5.850	6.825	6.775	5.325	0.895	3.525	0.028	ppbv
n-Decane	0.206	0.159	0.144	0.239	0.066	0.081	0.020	ppbv
n-Dodecane	0.233	0.223	0.178	0.373	0.116	0.223	0.035	ppbv
n-Heptane	0.601	0.750	0.813	0.457	0.095	0.386	0.029	ppbv
n-Hexane	1.380	1.733	1.817	1.135	0.215	0.818	0.038	ppbv
n-Nonane	0.181	0.158	0.153	0.148	0.034	0.083	0.019	ppbv
n-Octane	0.370	0.424	0.430	0.281	0.067	0.215	0.030	ppbv
n-Pentane	2.720	3.640	3.480	2.660	0.474	1.784	0.020	ppbv
n-Propylbenzene	0.035	0.026	0.023	0.035	0.011	0.011	0.021	ppbv
n-Tridecane	0.057	0.048	0.047	0.092	0.016	0.041	0.032	ppbv
n-Undecane	0.265	0.250	0.215	0.432	0.147	0.184	0.015	ppbv
o-Ethyltoluene	0.051	0.048	0.045	0.055	0.016	0.016	0.032	ppbv
o-Xylene	0.100	0.163	0.098	0.211	0.011	0.054	0.021	ppbv
p-Diethylbenzene	0.022	0.014	0.020	0.006	0.006	0.006	0.012	ppbv
p-Ethyltoluene	0.060	0.071	0.075	0.052	0.014	0.014	0.029	ppbv
Propane	18.0	17.6	18.0	14.8	2.8	11.1	0.060	ppbv
Propylene	0.222	0.161	0.142	0.157	0.169	0.133	0.023	ppbv
Propyne	0.030	0.030	0.030	0.030	0.030	0.030	0.060	ppbv
Styrene	0.016	0.016	0.016	0.016	0.016	0.016	0.031	ppbv
Toluene	0.653	0.926	0.864	0.700	0.143	0.481	0.047	ppbv
trans-2-Butene	0.016	0.041	0.016	0.016	0.054	0.036	0.033	ppbv
trans-2-Hexene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
trans-2-Pentene	0.019	0.019	0.019	0.019	0.019	0.019	0.038	ppbv
SNMOC (Sum of Knowns)	328	348	343	283	62	210		ppbC
Sum of Unknowns	52	71	61	78	53	45		ppbC
TNMOC	380	419	404	361	115	255		ppbC

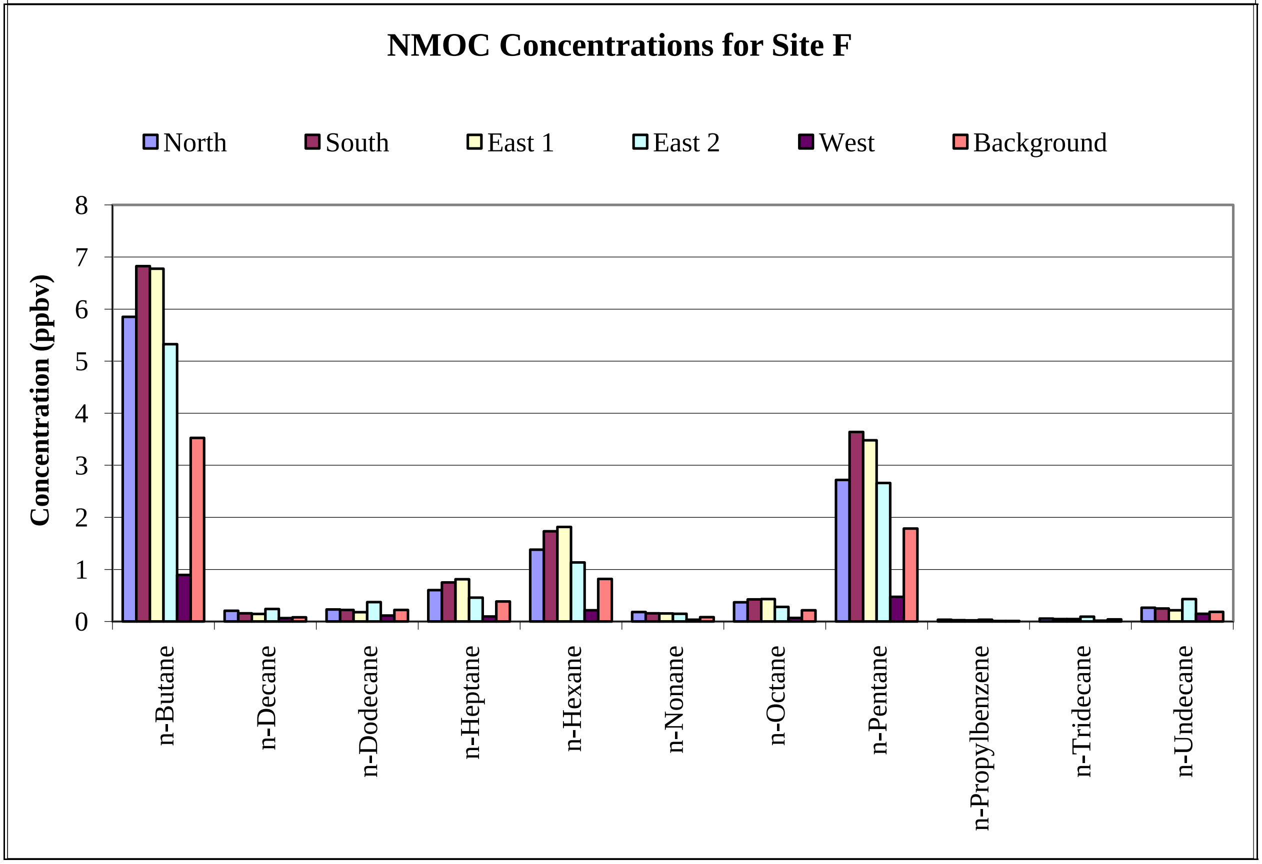

NMOC Concentrations for Site F
North
South
East 1
East 2
West
Background
Concentration (ppbv)
0.3
0.2
0.1
0.0
1,2,3-Trimethylbenzene
1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene
1,3-Butadiene
1-Decene
1-Dodecene
1-Heptene
1-Hexene
1-Nonene
1-Octene
1-Pentene

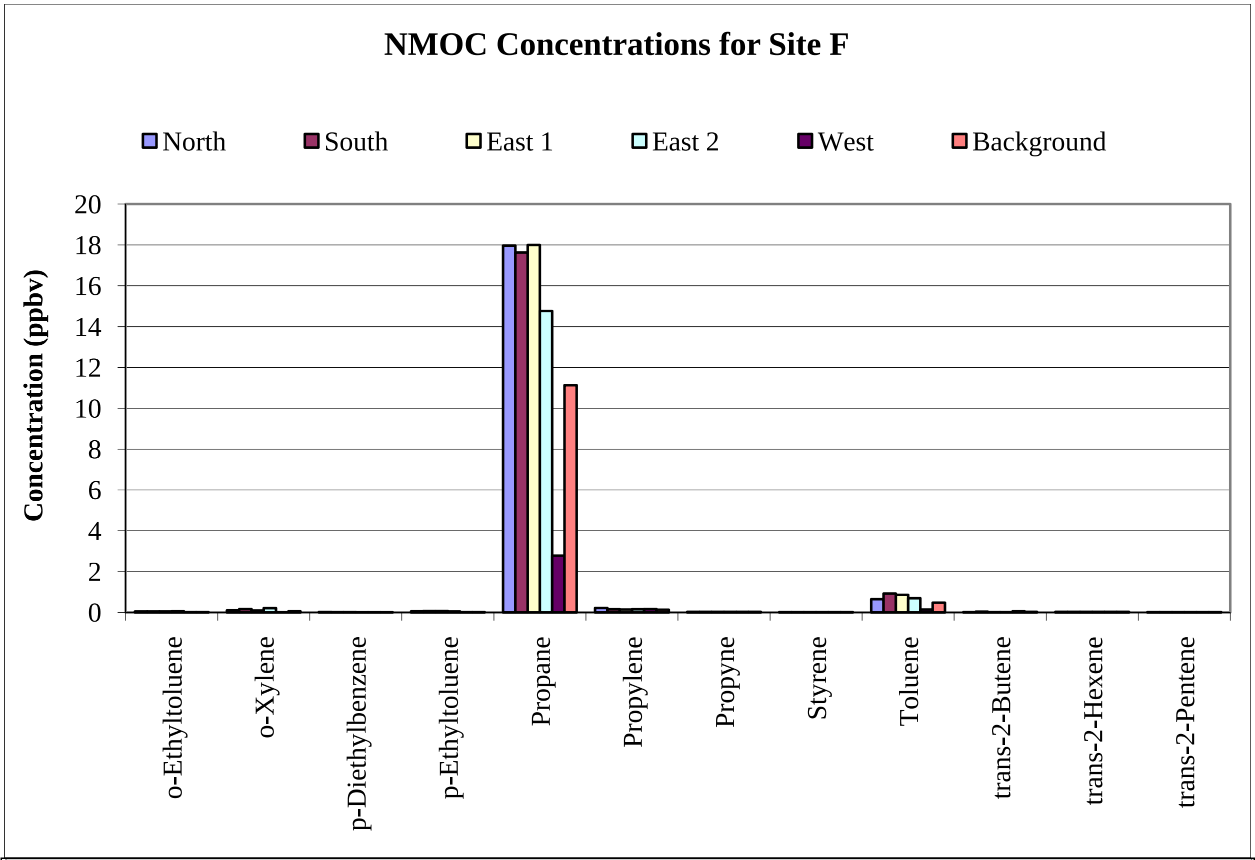

NMOC Concentrations for Site F
North
South
East 1
East 2
West
Background
Concentration (ppbv)
0.4
0.3
0.2
0.1
0.0
1-Tridecene
1-Undecene
2,2,3-Trimethylpentane
2,2,4-Trimethylpentane
2,2-Dimethylbutane
2,3,4-Trimethylpentane
2,3-Dimethylbutane
2,3-Dimethylpentane
2,4-Dimethylpentane
2-Ethyl-1-butene
2-Methyl-1-butene


NMOC Concentrations for Site F
North
South
East 1
East 2
West
Background
Concentration (ppbv)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2-Methyl-1-pentene
2-Methyl-2-butene
2-Methylheptane
2-Methylhexane
2-Methylpentane
3-Methyl-1-butene
3-Methylheptane
3-Methylhexane
3-Methylpentane
4-Methyl-1-pentene
Acetylene

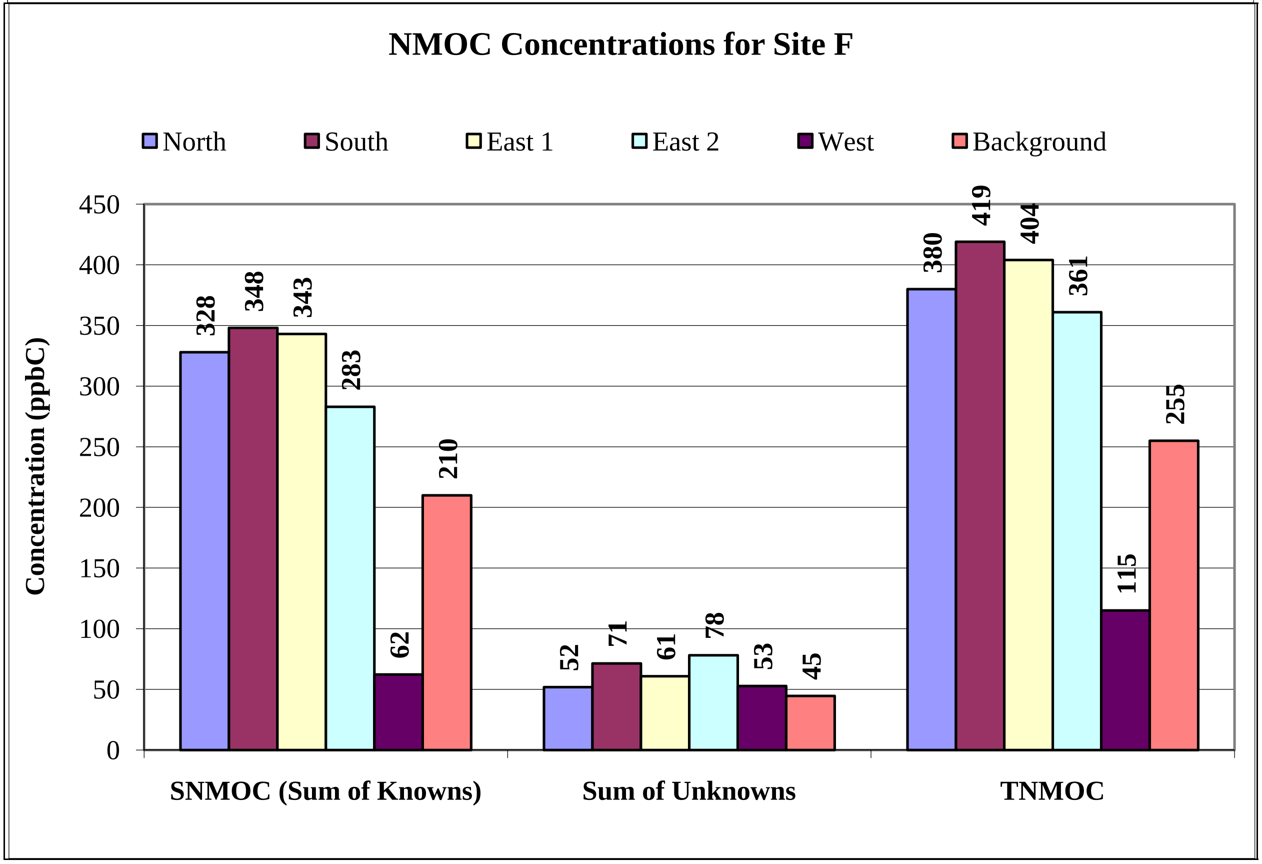

NMOC Concentrations for Site F
North
South
East 1
East 2
West
Background
Concentration (ppbv)
45
40
35
30
25
20
15
10
5
0
a-Pinene
Benzene
b-Pinene
cis-2-Butene
cis-2-Hexene
cis-2-Pentene
Cyclohexane
Cyclopentane
Cyclopentene
Ethane
Ethylbenzene


NMOC Concentrations for Site F
North
South
East 1
East 2
West
Background
Concentration (ppbv)
0
1
2
3
4
5
6
7
Ethylene
Isobutane
Isobutene/1-Butene
Isopentane
Isoprene
Isopropylbenzene
m-Diethylbenzene
Methylcyclohexane
Methylcyclopentane
m-Ethyltoluene
m-Xylene/p-Xylene


NMOC Concentrations for Site F
North
South
East 1
East 2
West
Background
Concentration (ppbv)
0
1
2
3
4
5
6
7
8
n-Butane
n-Decane
n-Dodecane
n-Heptane
n-Hexane
n-Nonane
n-Octane
n-Pentane
n-Propylbenzene
n-Tridecane
n-Undecane



NMOC Concentrations for Site F



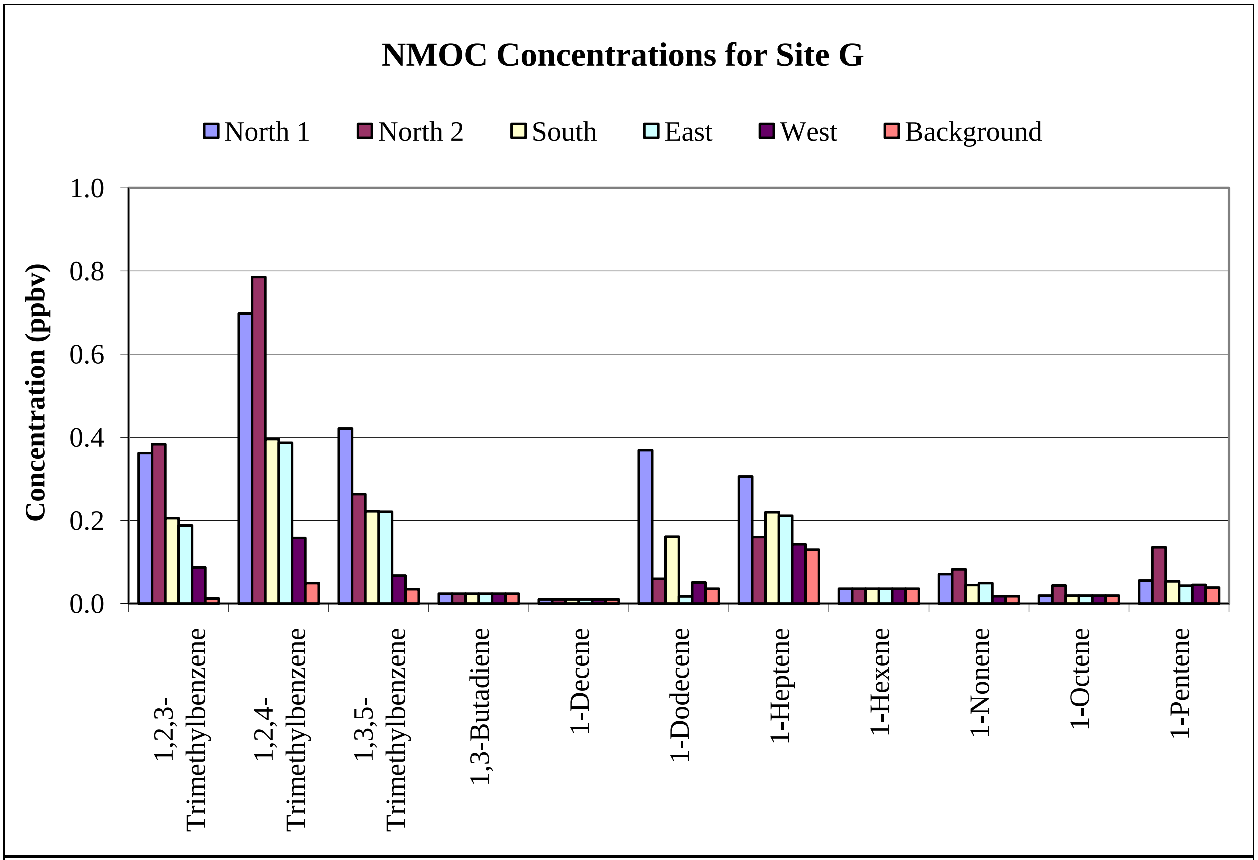
NMOC Concentrations for Site F

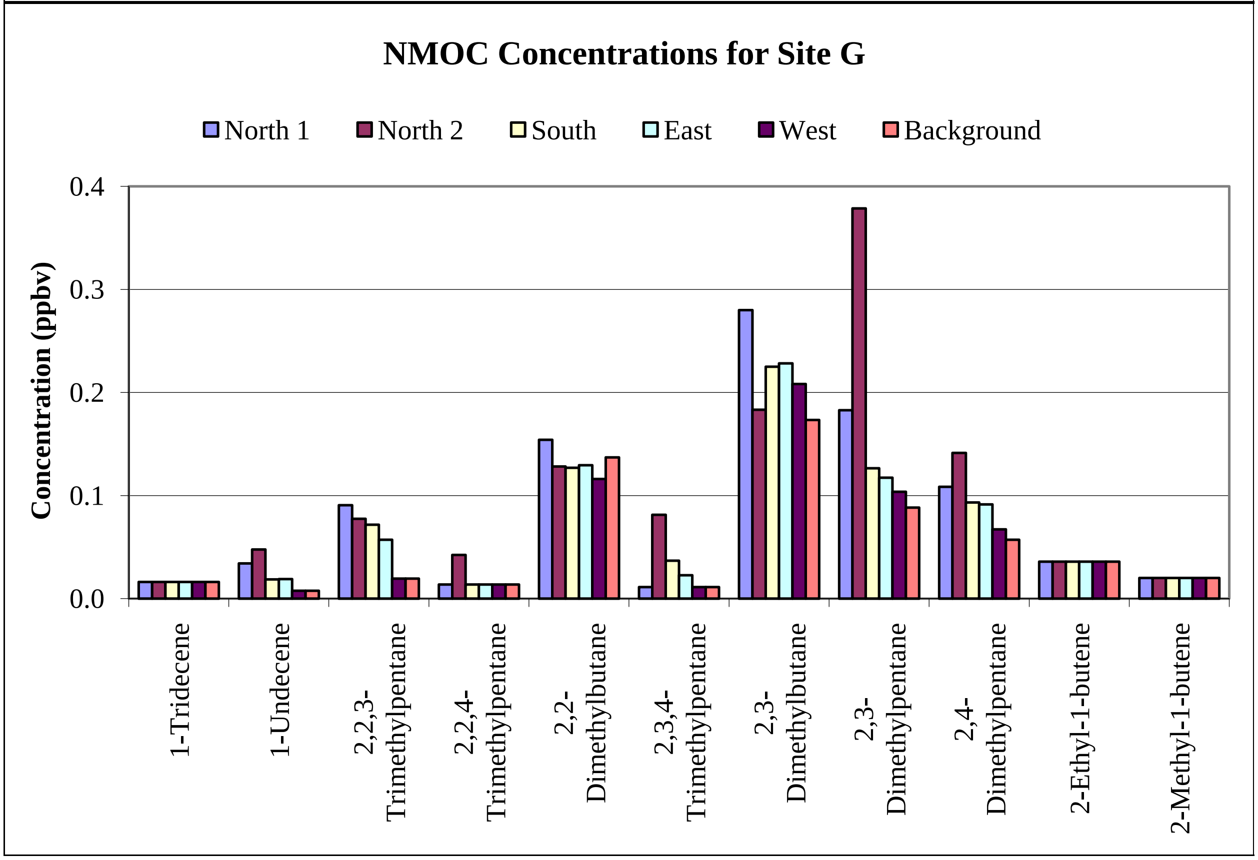
APPENDIX G – SITE G NMOC DATA AND GRAPHS

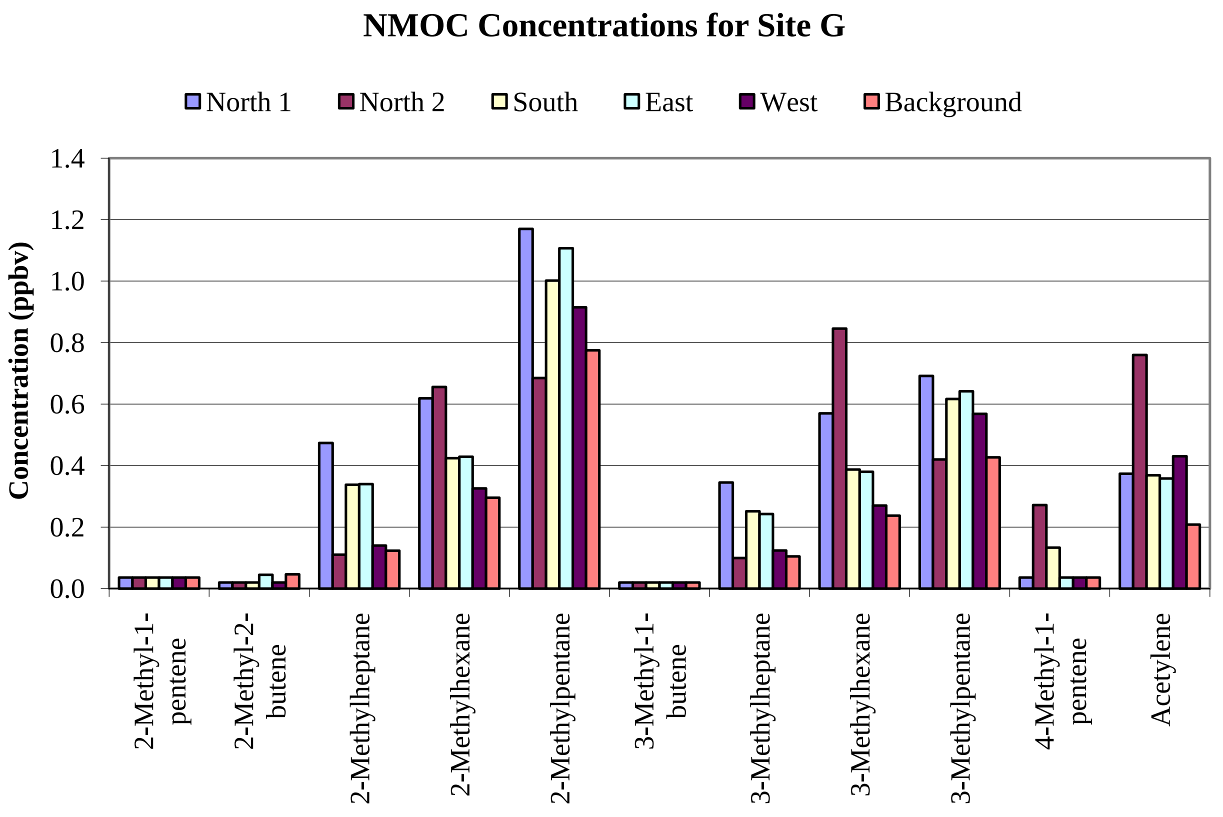
***NOTE – All table and graph values represent 25 hour sampling periods.**

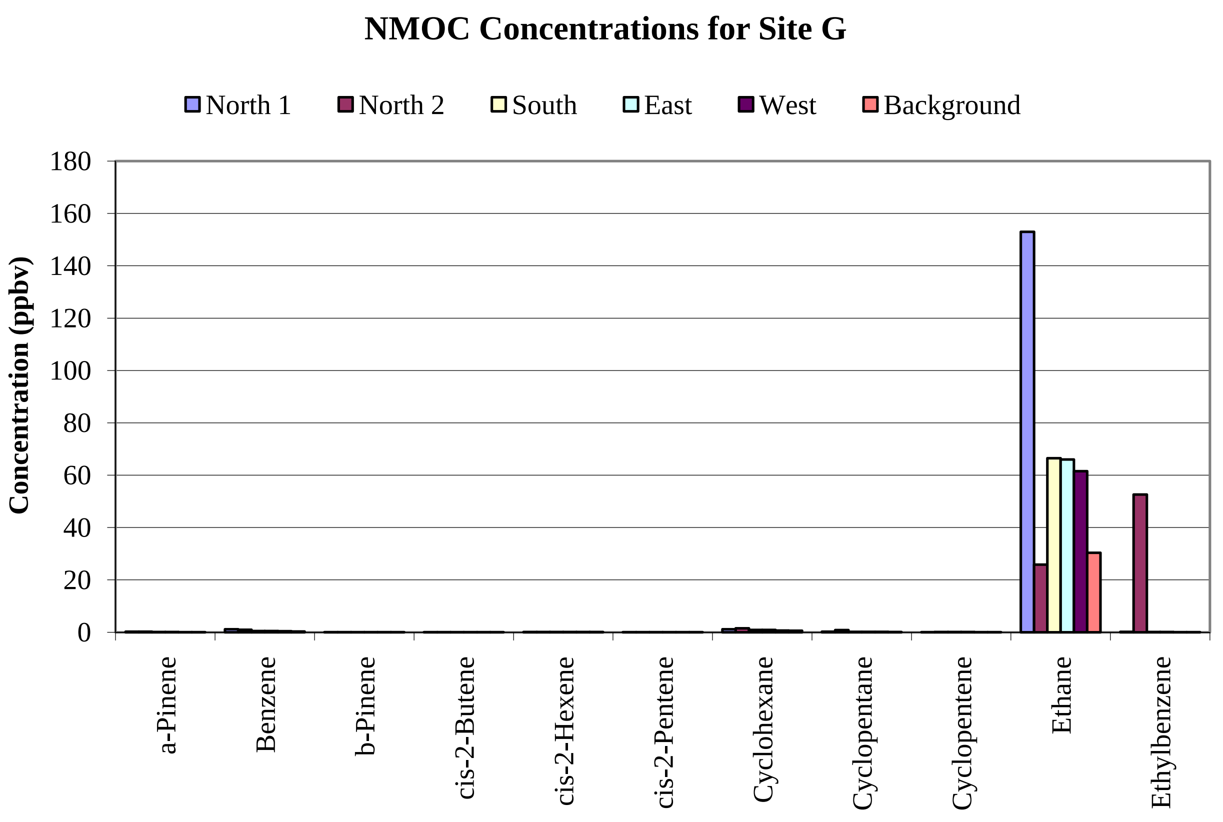
ANALYTE	Results						DL	UNITS
	North 1	**North 2**	**South**	**East**	**West**	**Background**		
1,2,3-Trimethylbenzene	0.362	0.383	0.206	0.188	0.087	0.012	0.024	ppbv
1,2,4-Trimethylbenzene	0.698	0.786	0.396	0.387	0.158	0.049	0.027	ppbv
1,3,5-Trimethylbenzene	0.421	0.263	0.222	0.221	0.067	0.035	0.022	ppbv
1,3-Butadiene	0.024	0.024	0.024	0.024	0.024	0.024	0.048	ppbv
1-Decene	0.010	0.010	0.010	0.010	0.010	0.010	0.020	ppbv
1-Dodecene	0.369	0.060	0.161	0.018	0.051	0.036	0.035	ppbv
1-Heptene	0.306	0.160	0.220	0.211	0.143	0.130	0.056	ppbv
1-Hexene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
1-Nonene	0.071	0.082	0.045	0.049	0.018	0.018	0.036	ppbv
1-Octene	0.019	0.044	0.019	0.019	0.019	0.019	0.039	ppbv
1-Pentene	0.056	0.136	0.054	0.043	0.045	0.039	0.024	ppbv
1-Tridecene	0.016	0.016	0.016	0.016	0.016	0.016	0.032	ppbv
1-Undecene	0.034	0.048	0.019	0.019	0.008	0.008	0.015	ppbv
2,2,3-Trimethylpentane	0.091	0.078	0.072	0.057	0.019	0.019	0.039	ppbv
2,2,4-Trimethylpentane	0.014	0.042	0.014	0.014	0.014	0.014	0.028	ppbv
2,2-Dimethylbutane	0.154	0.128	0.127	0.130	0.116	0.137	0.023	ppbv
2,3,4-Trimethylpentane	0.011	0.081	0.037	0.023	0.011	0.011	0.023	ppbv
2,3-Dimethylbutane	0.280	0.183	0.225	0.228	0.208	0.173	0.033	ppbv
2,3-Dimethylpentane	0.183	0.379	0.127	0.117	0.104	0.088	0.056	ppbv
2,4-Dimethylpentane	0.109	0.141	0.093	0.091	0.067	0.057	0.034	ppbv
2-Ethyl-1-butene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
2-Methyl-1-butene	0.020	0.020	0.020	0.020	0.020	0.020	0.040	ppbv
2-Methyl-1-pentene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
2-Methyl-2-butene	0.020	0.020	0.020	0.045	0.020	0.046	0.040	ppbv
2-Methylheptane	0.474	0.110	0.338	0.340	0.140	0.123	0.023	ppbv
2-Methylhexane	0.619	0.656	0.424	0.429	0.326	0.296	0.026	ppbv
2-Methylpentane	1.170	0.685	1.002	1.107	0.915	0.775	0.013	ppbv
3-Methyl-1-butene	0.020	0.020	0.020	0.020	0.020	0.020	0.040	ppbv
3-Methylheptane	0.345	0.100	0.251	0.243	0.124	0.105	0.025	ppbv
3-Methylhexane	0.570	0.846	0.387	0.380	0.270	0.237	0.033	ppbv
3-Methylpentane	0.692	0.420	0.617	0.642	0.568	0.427	0.030	ppbv
4-Methyl-1-pentene	0.036	0.272	0.133	0.036	0.036	0.036	0.072	ppbv
Acetylene	0.374	0.760	0.369	0.358	0.431	0.208	0.055	ppbv
a-Pinene	0.186	0.202	0.107	0.115	0.053	0.046	0.032	ppbv
Benzene	1.123	0.953	0.458	0.433	0.417	0.278	0.040	ppbv
b-Pinene	0.010	0.010	0.010	0.038	0.058	0.031	0.020	ppbv
cis-2-Butene	0.024	0.024	0.024	0.024	0.024	0.024	0.048	ppbv
cis-2-Hexene	0.082	0.084	0.074	0.085	0.080	0.086	0.072	ppbv
cis-2-Pentene	0.019	0.019	0.019	0.019	0.019	0.019	0.038	ppbv
Cyclohexane	1.157	1.517	0.872	0.882	0.643	0.558	0.037	ppbv
Cyclopentane	0.185	0.848	0.142	0.141	0.136	0.117	0.016	ppbv
Cyclopentene	0.055	0.096	0.066	0.100	0.062	0.059	0.040	ppbv
Ethane	153.0	25.9	66.5	66.0	61.5	30.4	0.045	ppbv

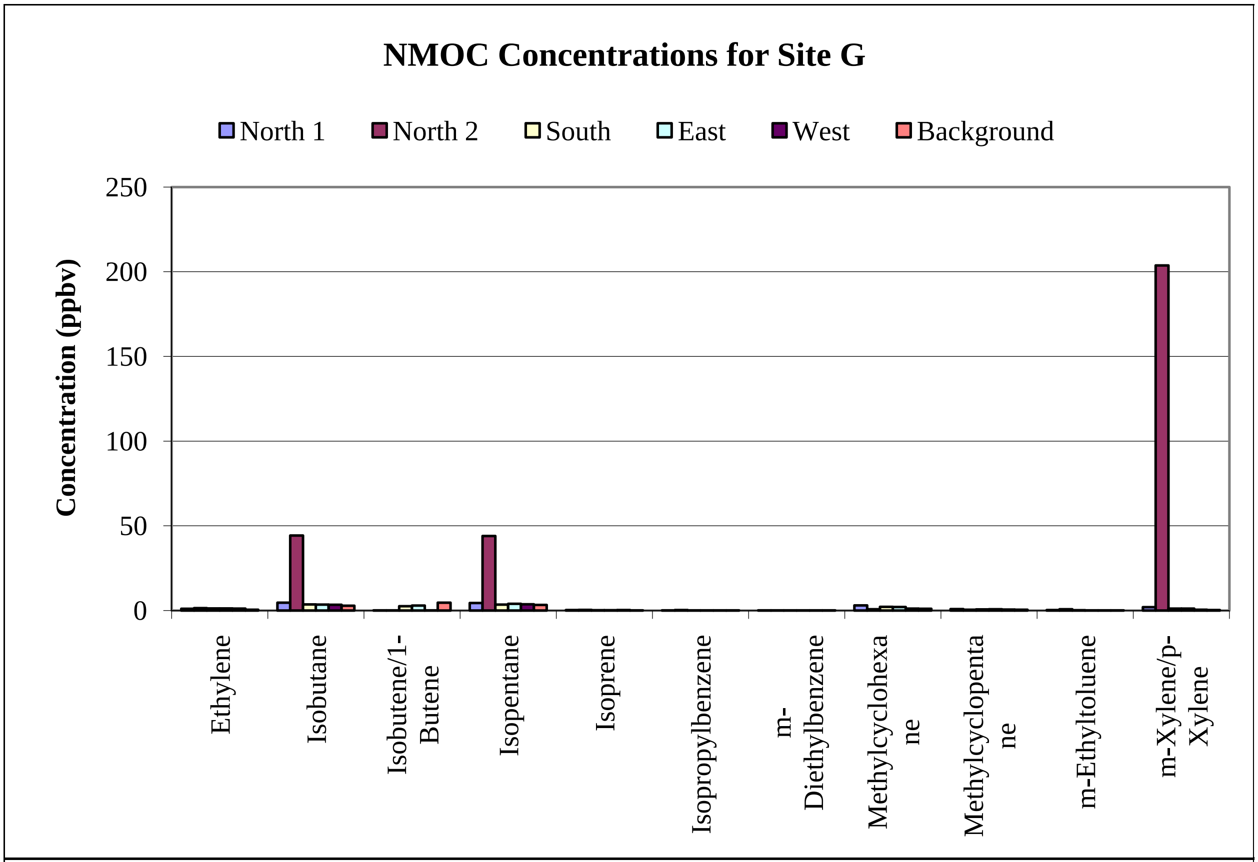
ANALYTE	Results						DL	UNITS
	North 1	North 2	South	East	West	Background		
Ethylbenzene	0.179	52.625	0.114	0.102	0.058	0.042	0.026	ppbv
Ethylene	1.015	1.390	1.250	1.245	1.120	0.446	0.035	ppbv
Isobutane	4.625	44.250	3.550	3.525	3.400	2.825	0.020	ppbv
Isobutene/1-Butene	0.018	0.018	2.600	2.925	0.018	4.650	0.035	ppbv
Isopentane	4.480	44.000	3.540	3.940	3.680	3.360	0.034	ppbv
Isoprene	0.250	0.412	0.169	0.170	0.262	0.100	0.040	ppbv
Isopropylbenzene	0.018	0.318	0.018	0.018	0.018	0.018	0.036	ppbv
m-Diethylbenzene	0.099	0.097	0.054	0.047	0.041	0.009	0.018	ppbv
Methylcyclohexane	3.071	0.764	2.171	2.114	1.149	1.034	0.021	ppbv
Methylcyclopentane	0.847	0.503	0.703	0.720	0.577	0.475	0.022	ppbv
m-Ethyltoluene	0.268	0.736	0.159	0.151	0.063	0.035	0.017	ppbv
m-Xylene/p-Xylene	2.013	203.750	1.164	1.141	0.460	0.295	0.039	ppbv
n-Butane	4.625	3.700	3.675	3.650	3.650	3.225	0.028	ppbv
n-Decane	1.170	1.820	0.616	0.628	0.298	0.119	0.020	ppbv
n-Dodecane	0.777	4.175	0.319	0.239	0.293	0.117	0.035	ppbv
n-Heptane	1.261	0.671	0.904	0.877	0.493	0.429	0.029	ppbv
n-Hexane	1.453	0.482	1.268	1.277	1.092	0.845	0.038	ppbv
n-Nonane	1.200	0.321	0.722	0.742	0.229	0.144	0.019	ppbv
n-Octane	1.450	0.341	1.078	1.000	0.380	0.370	0.030	ppbv
n-Pentane	2.160	187.600	1.782	1.798	1.750	1.582	0.020	ppbv
n-Propylbenzene	0.097	0.332	0.058	0.055	0.029	0.011	0.021	ppbv
n-Tridecane	0.278	0.434	0.094	0.059	0.072	0.016	0.032	ppbv
n-Undecane	1.091	4.818	0.487	0.475	0.374	0.145	0.015	ppbv
o-Ethyltoluene	0.259	0.351	0.148	0.138	0.066	0.016	0.032	ppbv
o-Xylene	0.339	43.875	0.196	0.194	0.088	0.057	0.021	ppbv
p-Diethylbenzene	0.145	0.071	0.066	0.072	0.040	0.016	0.012	ppbv
p-Ethyltoluene	0.210	0.306	0.124	0.116	0.049	0.014	0.029	ppbv
Propane	24.9	9.4	15.1	15.0	14.4	12.7	0.060	ppbv
Propylene	0.306	0.387	0.360	0.312	0.264	0.210	0.023	ppbv
Propyne	0.030	0.030	0.030	0.030	0.030	0.030	0.060	ppbv
Styrene	0.016	1.388	0.016	0.016	0.016	0.016	0.031	ppbv
Toluene	2.143	9.214	1.197	1.164	0.724	0.544	0.047	ppbv
trans-2-Butene	0.053	0.670	0.054	0.053	0.053	0.046	0.033	ppbv
trans-2-Hexene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
trans-2-Pentene	0.048	0.048	0.019	0.019	0.019	0.019	0.038	ppbv
SNMOC (Sum of Knowns)	676	4150	389	386	311	230		ppbC
Sum of Unknowns	220	403	107	97	88	52		ppbC
TNMOC	896	4560	495	483	399	282		ppbC

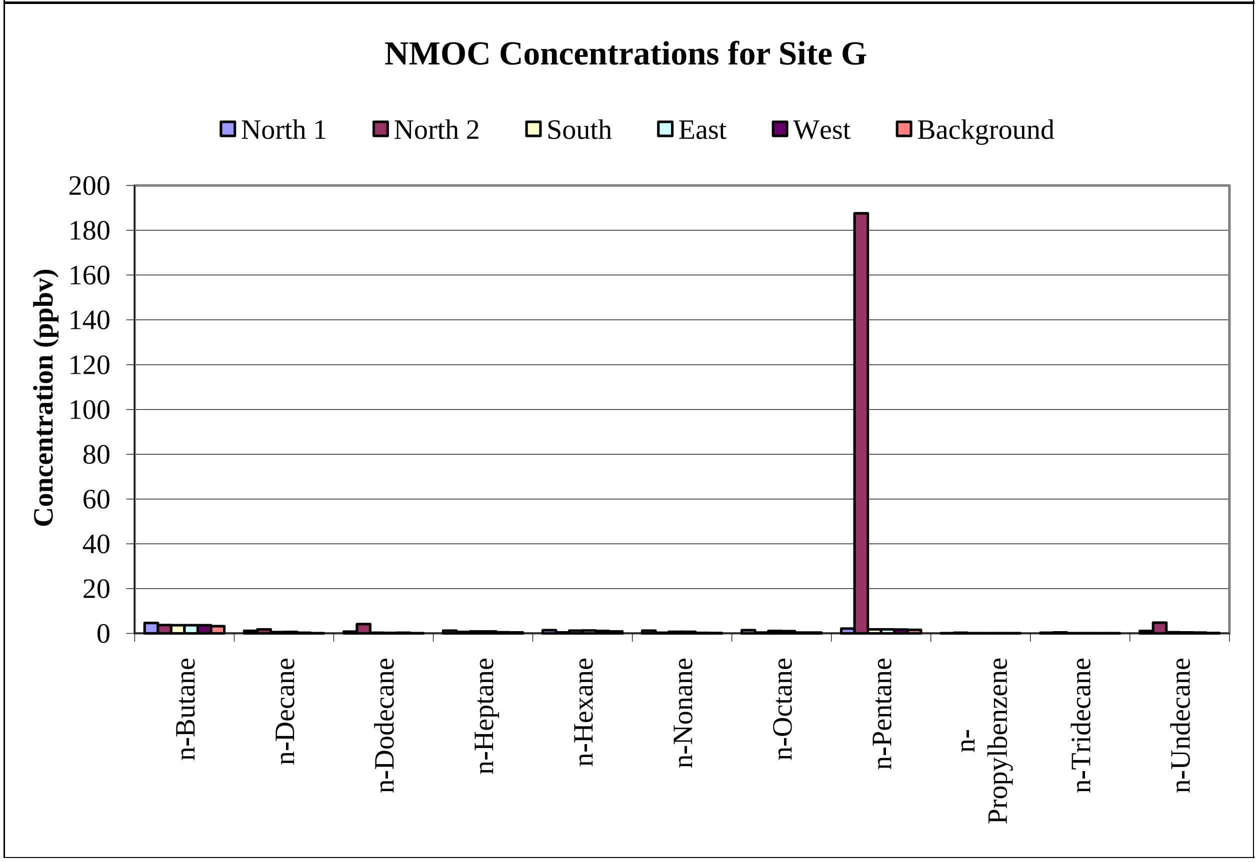

NMOC Concentrations for Site G
North 1
North 2
South
East
West
Background
Concentration (ppbv)
1.0
0.8
0.6
0.4
0.2
0.0
1,2,3-Trimethylbenzene
1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene
1,3-Butadiene
1-Decene
1-Dodecene
1-Heptene
1-Hexene
1-Nonene
1-Octene
1-Pentene

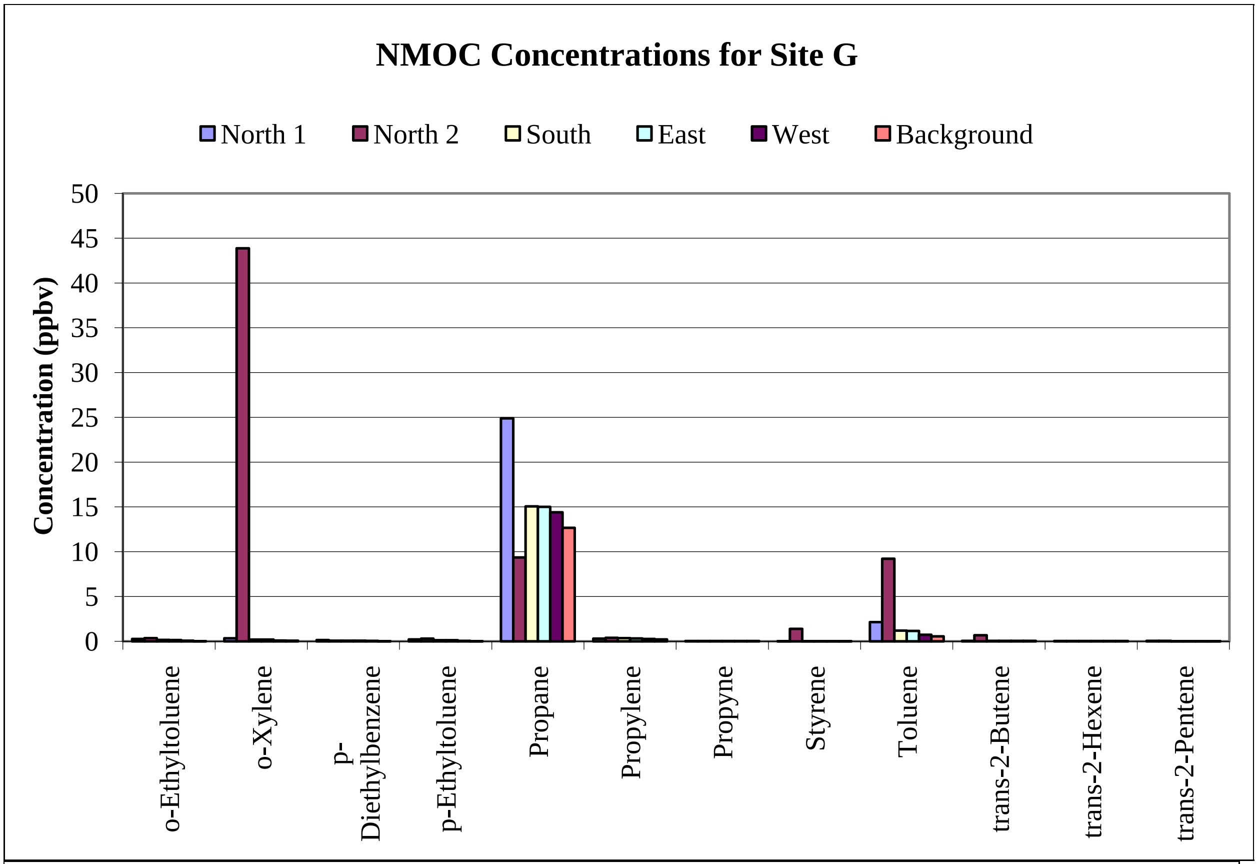

NMOC Concentrations for Site G
North 1
North 2
South
East
West
Background
Concentration (ppbv)
0.4
0.3
0.2
0.1
0.0
1-Tridecene
1-Undecene
2,2,3-Trimethylpentane
2,2,4-Trimethylpentane
2,2-Dimethylbutane
2,3,4-Trimethylpentane
2,3-Dimethylbutane
2,3-Dimethylpentane
2,4-Dimethylpentane
2-Ethyl-1-butene
2-Methyl-1-butene

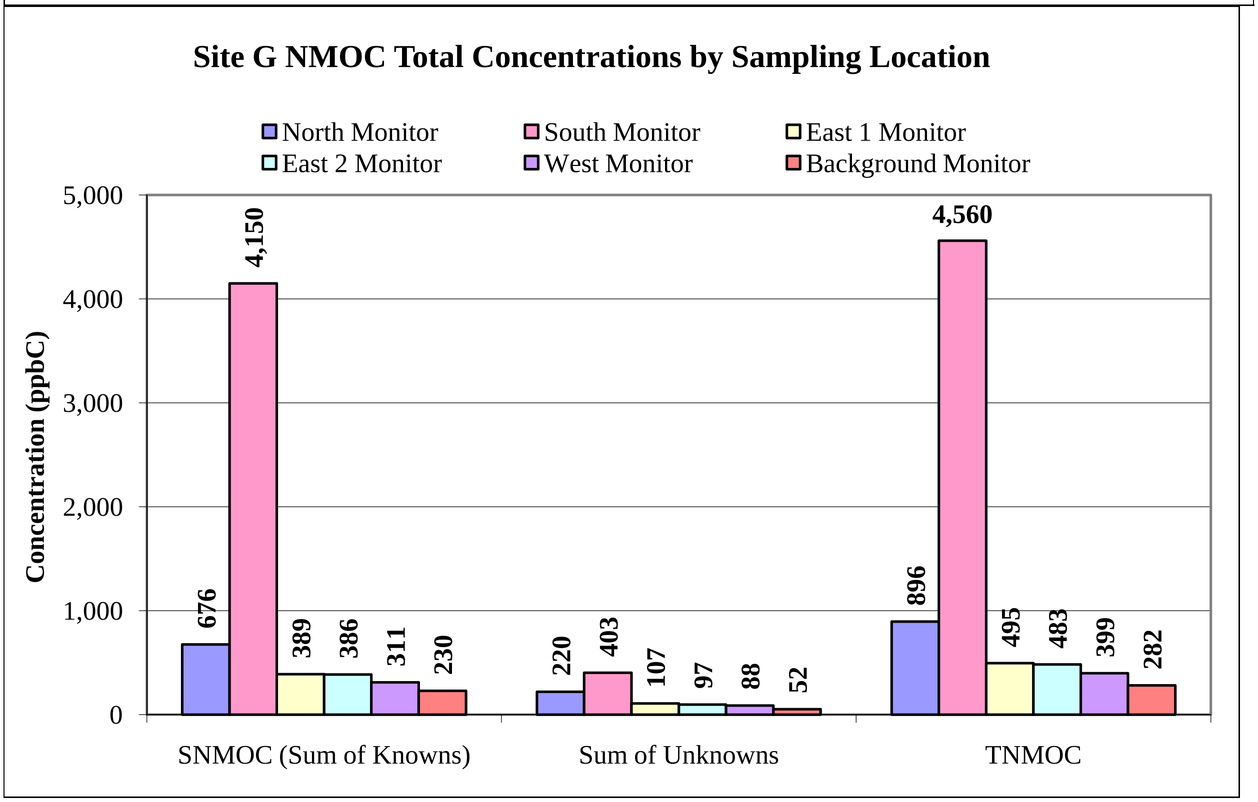

NMOC Concentrations for Site G
North 1
North 2
South
East
West
Background
Concentration (ppbv)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2-Methyl-1-pentene
2-Methyl-2-butene
2-Methylheptane
2-Methylhexane
2-Methylpentane
3-Methyl-1-butene
3-Methylheptane
3-Methylhexane
3-Methylpentane
4-Methyl-1-pentene
Acetylene


NMOC Concentrations for Site G
North 1
North 2
South
East
West
Background
Concentration (ppbv)
180
160
140
120
100
80
60
40
20
0
a-Pinene
Benzene
b-Pinene
cis-2-Butene
cis-2-Hexene
cis-2-Pentene
Cyclohexane
Cyclopentane
Cyclopentene
Ethane
Ethylbenzene


NMOC Concentrations for Site G
North 1
North 2
South
East
West
Background
Concentration (ppbv)
250
200
150
100
50
0
Ethylene
Isobutane
Isobutene/1-Butene
Isopentane
Isoprene
Isopropylbenzene
m-Diethylbenzene
Methylcyclohexane
Methylcyclopentane
m-Ethyltoluene
m-Xylene/p-Xylene


NMOC Concentrations for Site G
North 1
North 2
South
East
West
Background
Concentration (ppbv)
200
180
160
140
120
100
80
60
40
20
0
n-Butane
n-Decane
n-Dodecane
n-Heptane
n-Hexane
n-Nonane
n-Octane
n-Pentane
n-Propylbenzene
n-Tridecane
n-Undecane


NMOC Concentrations for Site G

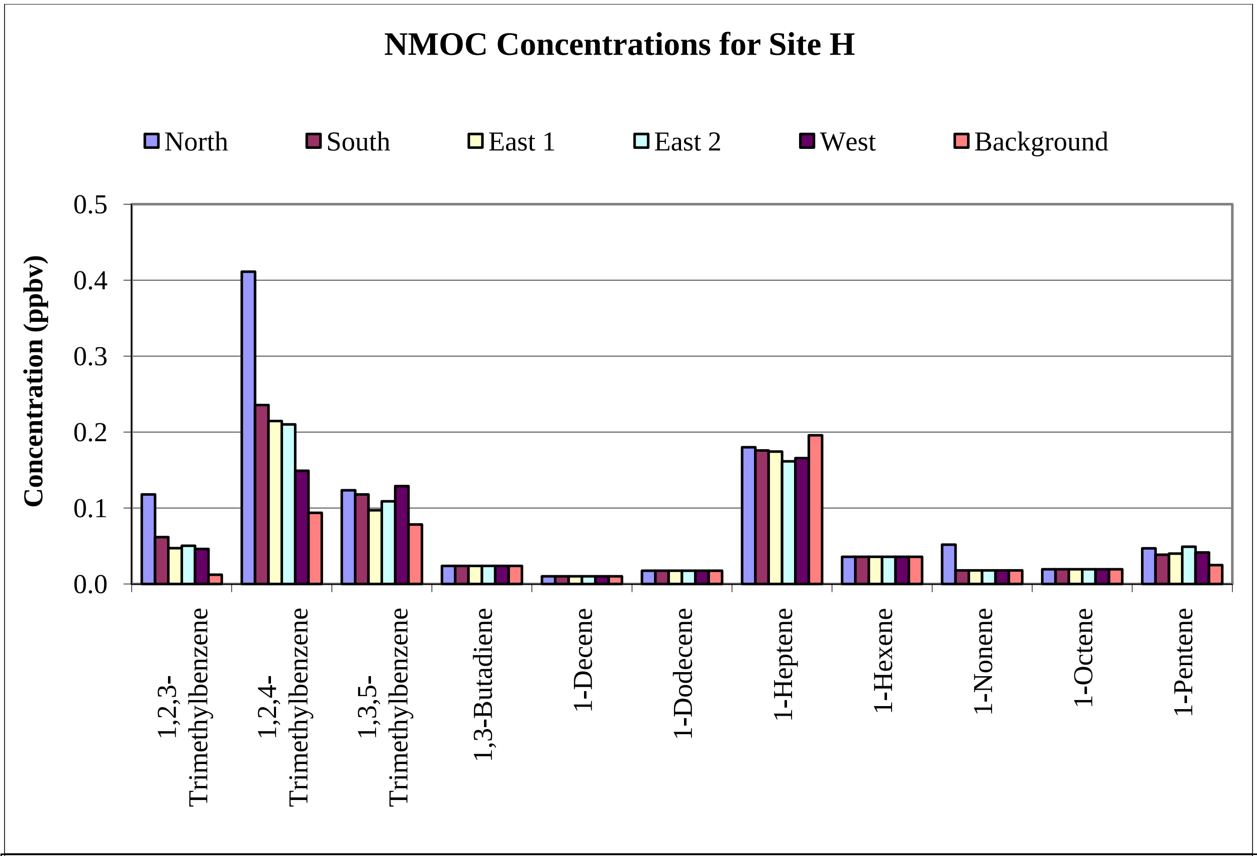

Site G NMOC Total Concentrations by Sampling Location

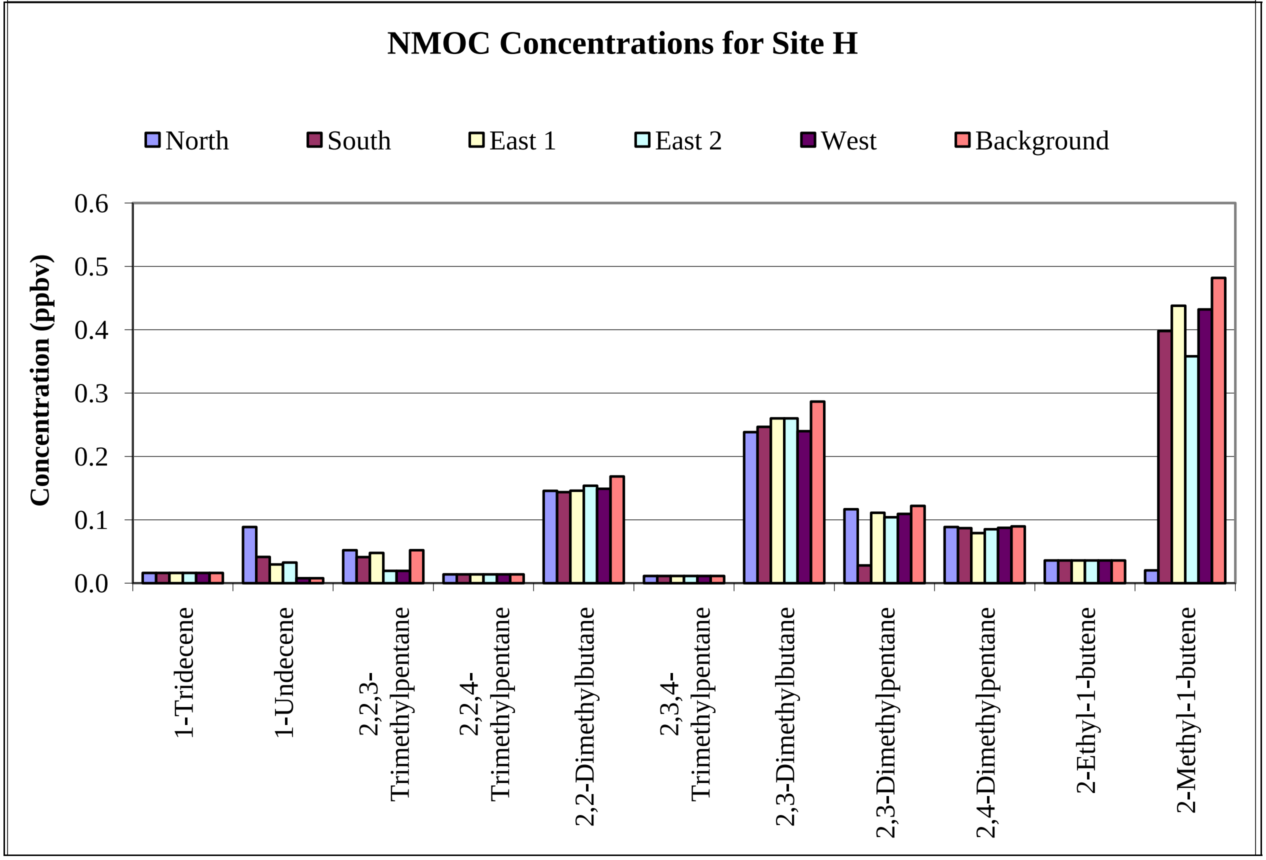
APPENDIX H – SITE H NMOC DATA AND GRAPHS

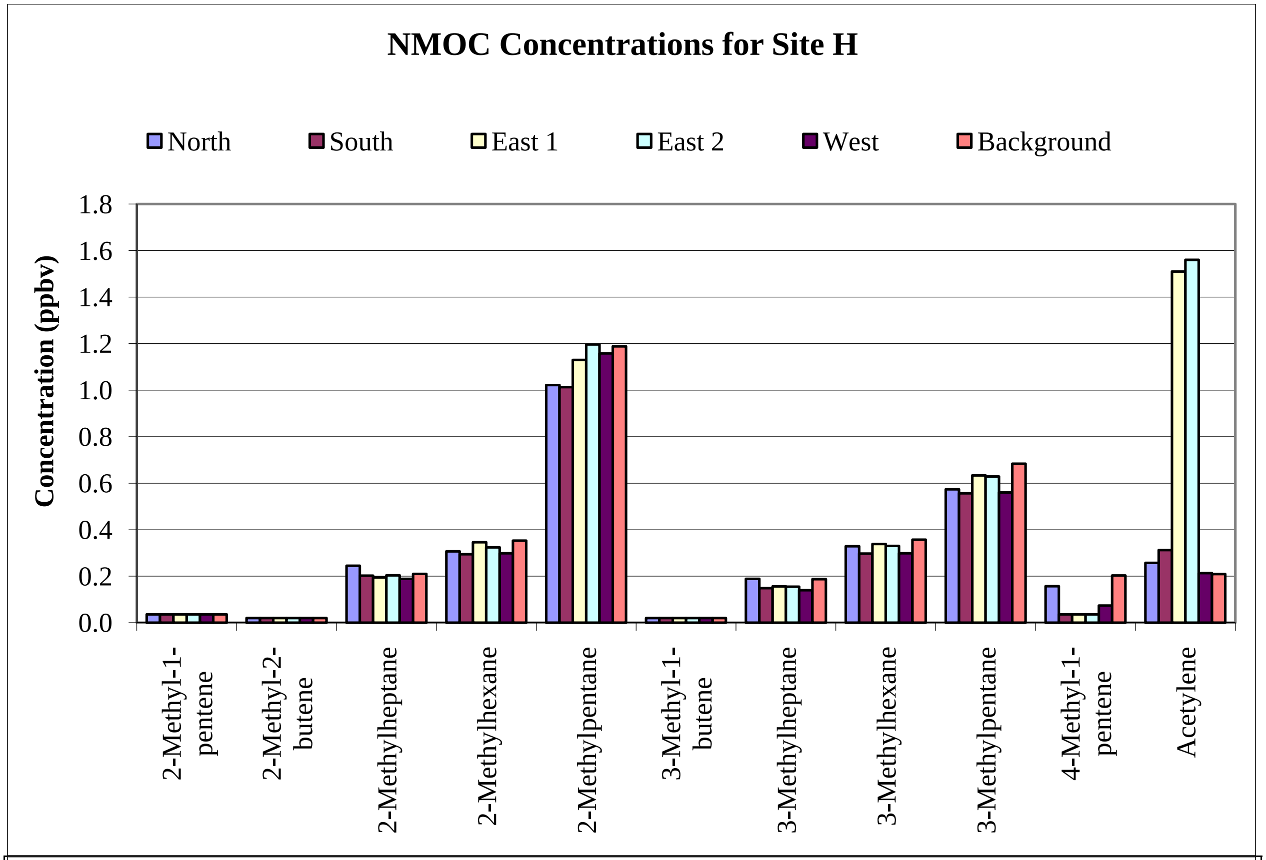
NOTE – All table and graph values represent 27 hour sampling periods.

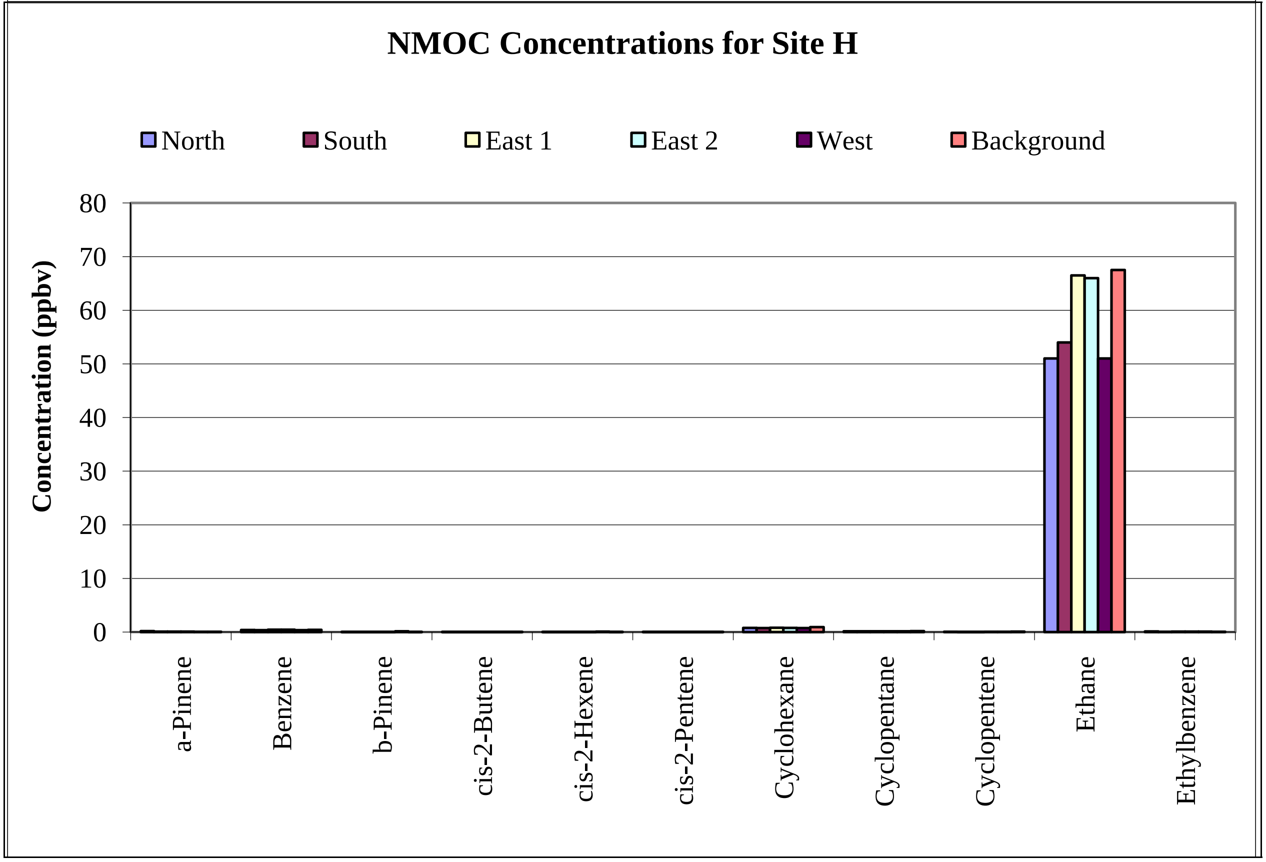
ANALYTE	Results						DL	UNITS
	North	**South**	**East 1**	**East 2**	**West**	**Background**		
1,2,3-Trimethylbenzene	0.118	0.062	0.047	0.050	0.046	0.012	0.024	ppbv
1,2,4-Trimethylbenzene	0.411	0.236	0.214	0.210	0.149	0.094	0.027	ppbv
1,3,5-Trimethylbenzene	0.123	0.118	0.097	0.109	0.129	0.078	0.022	ppbv
1,3-Butadiene	0.024	0.024	0.024	0.024	0.024	0.024	0.048	ppbv
1-Decene	0.010	0.010	0.010	0.010	0.010	0.010	0.020	ppbv
1-Dodecene	0.018	0.018	0.018	0.018	0.018	0.018	0.035	ppbv
1-Heptene	0.180	0.176	0.174	0.161	0.166	0.196	0.056	ppbv
1-Hexene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
1-Nonene	0.052	0.018	0.018	0.018	0.018	0.018	0.036	ppbv
1-Octene	0.019	0.019	0.019	0.019	0.019	0.019	0.039	ppbv
1-Pentene	0.047	0.038	0.040	0.049	0.041	0.025	0.024	ppbv
1-Tridecene	0.016	0.016	0.016	0.016	0.016	0.016	0.032	ppbv
1-Undecene	0.089	0.041	0.029	0.033	0.008	0.008	0.015	ppbv
2,2,3-Trimethylpentane	0.052	0.041	0.048	0.019	0.019	0.052	0.039	ppbv
2,2,4-Trimethylpentane	0.014	0.014	0.014	0.014	0.014	0.014	0.028	ppbv
2,2-Dimethylbutane	0.146	0.144	0.146	0.154	0.149	0.168	0.023	ppbv
2,3,4-Trimethylpentane	0.011	0.011	0.011	0.011	0.011	0.011	0.023	ppbv
2,3-Dimethylbutane	0.238	0.247	0.260	0.260	0.240	0.287	0.033	ppbv
2,3-Dimethylpentane	0.117	0.028	0.111	0.104	0.109	0.122	0.056	ppbv
2,4-Dimethylpentane	0.089	0.087	0.079	0.085	0.087	0.090	0.034	ppbv
2-Ethyl-1-butene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
2-Methyl-1-butene	0.020	0.398	0.438	0.358	0.432	0.482	0.040	ppbv
2-Methyl-1-pentene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
2-Methyl-2-butene	0.020	0.020	0.020	0.020	0.020	0.020	0.040	ppbv
2-Methylheptane	0.245	0.203	0.195	0.204	0.189	0.210	0.023	ppbv
2-Methylhexane	0.307	0.294	0.346	0.324	0.299	0.353	0.026	ppbv
2-Methylpentane	1.022	1.013	1.130	1.197	1.158	1.188	0.013	ppbv
3-Methyl-1-butene	0.020	0.020	0.020	0.020	0.020	0.020	0.040	ppbv
3-Methylheptane	0.189	0.149	0.156	0.155	0.140	0.188	0.025	ppbv
3-Methylhexane	0.329	0.297	0.339	0.330	0.299	0.357	0.033	ppbv
3-Methylpentane	0.573	0.557	0.633	0.628	0.560	0.683	0.030	ppbv
4-Methyl-1-pentene	0.157	0.036	0.036	0.036	0.074	0.203	0.072	ppbv
Acetylene	0.257	0.313	1.510	1.560	0.213	0.209	0.055	ppbv
a-Pinene	0.162	0.083	0.100	0.075	0.061	0.059	0.032	ppbv
Benzene	0.383	0.362	0.445	0.437	0.350	0.405	0.040	ppbv
b-Pinene	0.010	0.010	0.010	0.027	0.134	0.010	0.020	ppbv
cis-2-Butene	0.024	0.024	0.024	0.024	0.024	0.024	0.048	ppbv
cis-2-Hexene	0.036	0.036	0.036	0.036	0.080	0.036	0.072	ppbv
cis-2-Pentene	0.019	0.019	0.019	0.019	0.019	0.019	0.038	ppbv
Cyclohexane	0.762	0.747	0.795	0.777	0.748	0.925	0.037	ppbv
Cyclopentane	0.143	0.145	0.161	0.159	0.155	0.175	0.016	ppbv
Cyclopentene	0.058	0.020	0.020	0.062	0.050	0.093	0.040	ppbv
Ethane	51.0	54.0	66.5	66.0	51.0	67.5	0.045	ppbv

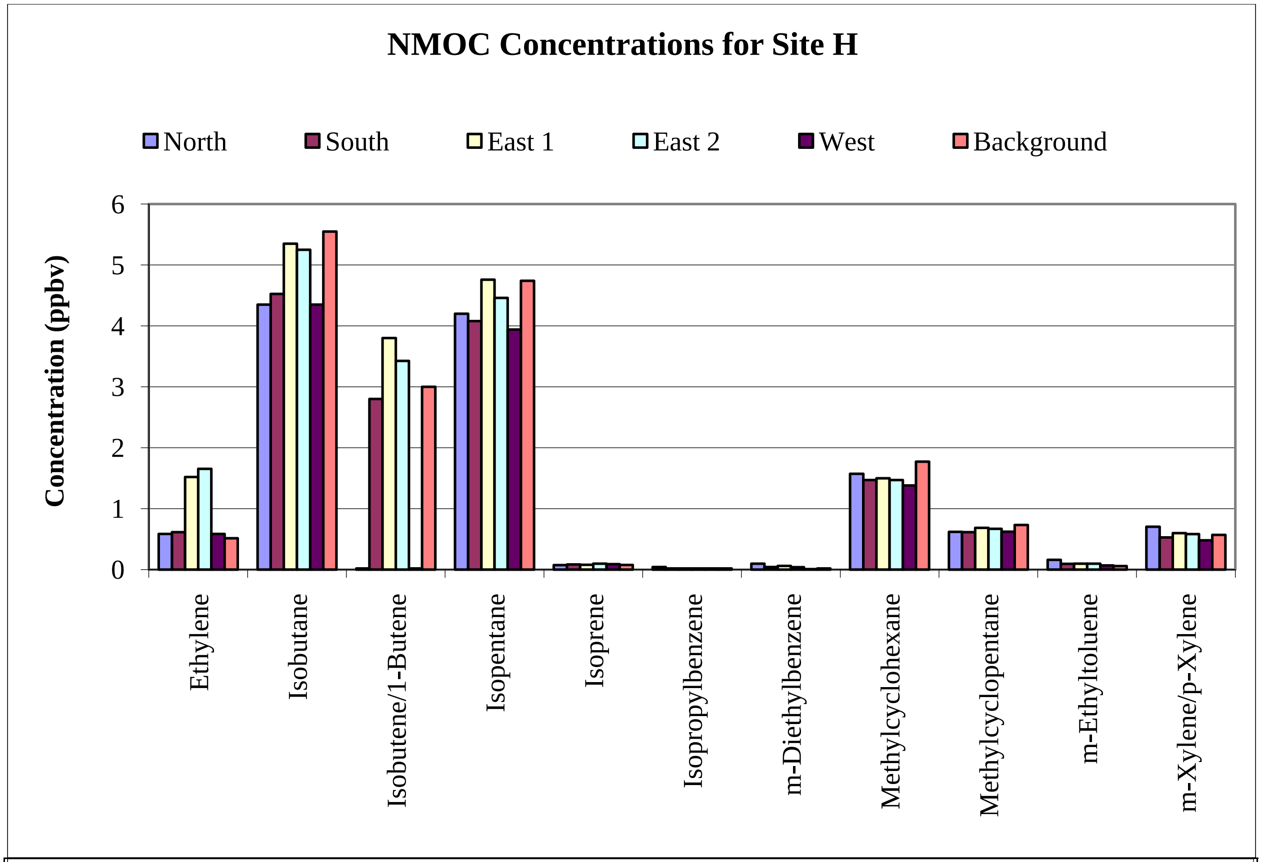
ANALYTE	Results						DL	UNITS
	North	South	East 1	East 2	West	Background		
Ethylbenzene	0.102	0.068	0.090	0.098	0.075	0.061	0.026	ppbv
Ethylene	0.585	0.615	1.520	1.655	0.585	0.515	0.035	ppbv
Isobutane	4.350	4.525	5.350	5.250	4.350	5.550	0.020	ppbv
Isobutene/1-Butene	0.018	2.800	3.800	3.425	0.018	3.000	0.035	ppbv
Isopentane	4.200	4.080	4.760	4.460	3.940	4.740	0.034	ppbv
Isoprene	0.074	0.085	0.080	0.096	0.089	0.076	0.040	ppbv
Isopropylbenzene	0.043	0.018	0.018	0.018	0.018	0.018	0.036	ppbv
m-Diethylbenzene	0.097	0.041	0.061	0.039	0.009	0.020	0.018	ppbv
Methylcyclohexane	1.571	1.471	1.500	1.471	1.381	1.771	0.021	ppbv
Methylcyclopentane	0.620	0.613	0.685	0.670	0.622	0.732	0.022	ppbv
m-Ethyltoluene	0.160	0.094	0.097	0.096	0.069	0.058	0.017	ppbv
m-Xylene/p-Xylene	0.703	0.528	0.598	0.584	0.480	0.569	0.039	ppbv
n-Butane	4.325	4.450	5.200	5.125	4.300	5.400	0.028	ppbv
n-Decane	0.878	0.512	0.399	0.397	0.332	0.215	0.020	ppbv
n-Dodecane	0.548	0.157	0.151	0.212	0.165	0.096	0.035	ppbv
n-Heptane	0.674	0.623	0.634	0.627	0.583	0.729	0.029	ppbv
n-Hexane	1.115	1.130	1.208	1.157	1.070	1.423	0.038	ppbv
n-Nonane	0.588	0.411	0.372	0.363	0.330	0.350	0.019	ppbv
n-Octane	0.709	0.561	0.549	0.616	0.641	0.623	0.030	ppbv
n-Pentane	2.040	2.060	2.300	2.260	1.988	2.460	0.020	ppbv
n-Propylbenzene	0.077	0.046	0.041	0.042	0.033	0.011	0.021	ppbv
n-Tridecane	0.222	0.016	0.016	0.073	0.067	0.016	0.032	ppbv
n-Undecane	0.885	0.431	0.332	0.370	0.286	0.161	0.015	ppbv
o-Ethyltoluene	0.170	0.106	0.092	0.089	0.065	0.053	0.032	ppbv
o-Xylene	0.163	0.117	0.136	0.138	0.097	0.097	0.021	ppbv
p-Diethylbenzene	0.066	0.038	0.006	0.038	0.006	0.020	0.012	ppbv
p-Ethyltoluene	0.151	0.082	0.070	0.085	0.051	0.062	0.029	ppbv
Propane	15.7	16.3	20.8	20.6	15.5	19.8	0.060	ppbv
Propylene	0.184	0.157	0.400	0.400	0.159	0.132	0.023	ppbv
Propyne	0.030	0.030	0.030	0.030	0.030	0.030	0.060	ppbv
Styrene	0.016	0.016	0.016	0.016	0.138	0.016	0.031	ppbv
Toluene	0.861	0.734	0.877	0.873	0.767	0.843	0.047	ppbv
trans-2-Butene	0.066	0.016	0.033	0.059	0.045	0.016	0.033	ppbv
trans-2-Hexene	0.036	0.036	0.036	0.036	0.036	0.036	0.072	ppbv
trans-2-Pentene	0.019	0.019	0.019	0.019	0.019	0.019	0.038	ppbv
SNMOC (Sum of Knowns)	345	333	396	393	309	387		ppbC
Sum of Unknowns	149	61	61	71	77	55		ppbC
TNMOC	495	394	457	464	387	443		ppbC

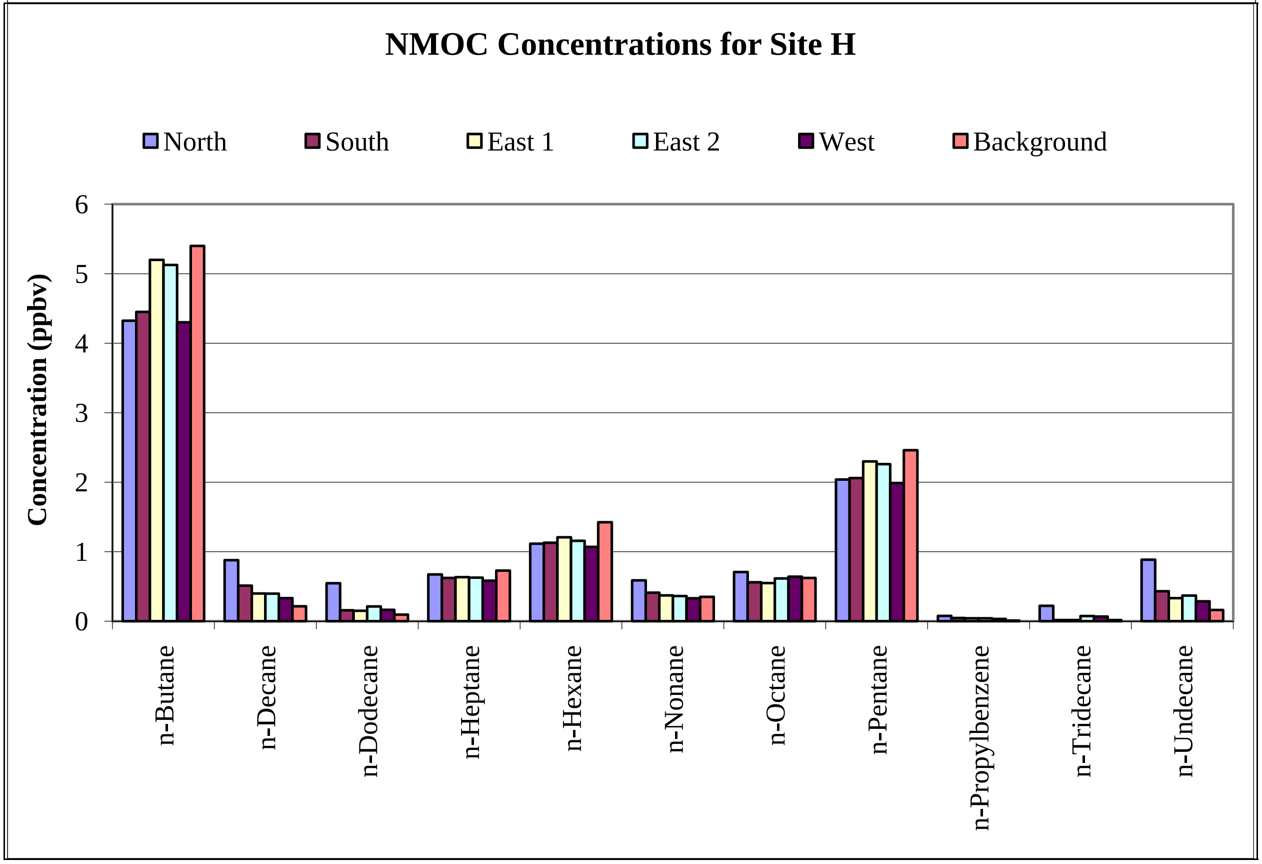

NMOC Concentrations for Site H
North
South
East 1
East 2
West
Background
Concentration (ppbv)
0.5
0.4
0.3
0.2
0.1
0.0
1,2,3-Trimethylbenzene
1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene
1,3-Butadiene
1-Decene
1-Dodecene
1-Heptene
1-Hexene
1-Nonene
1-Octene
1-Pentene

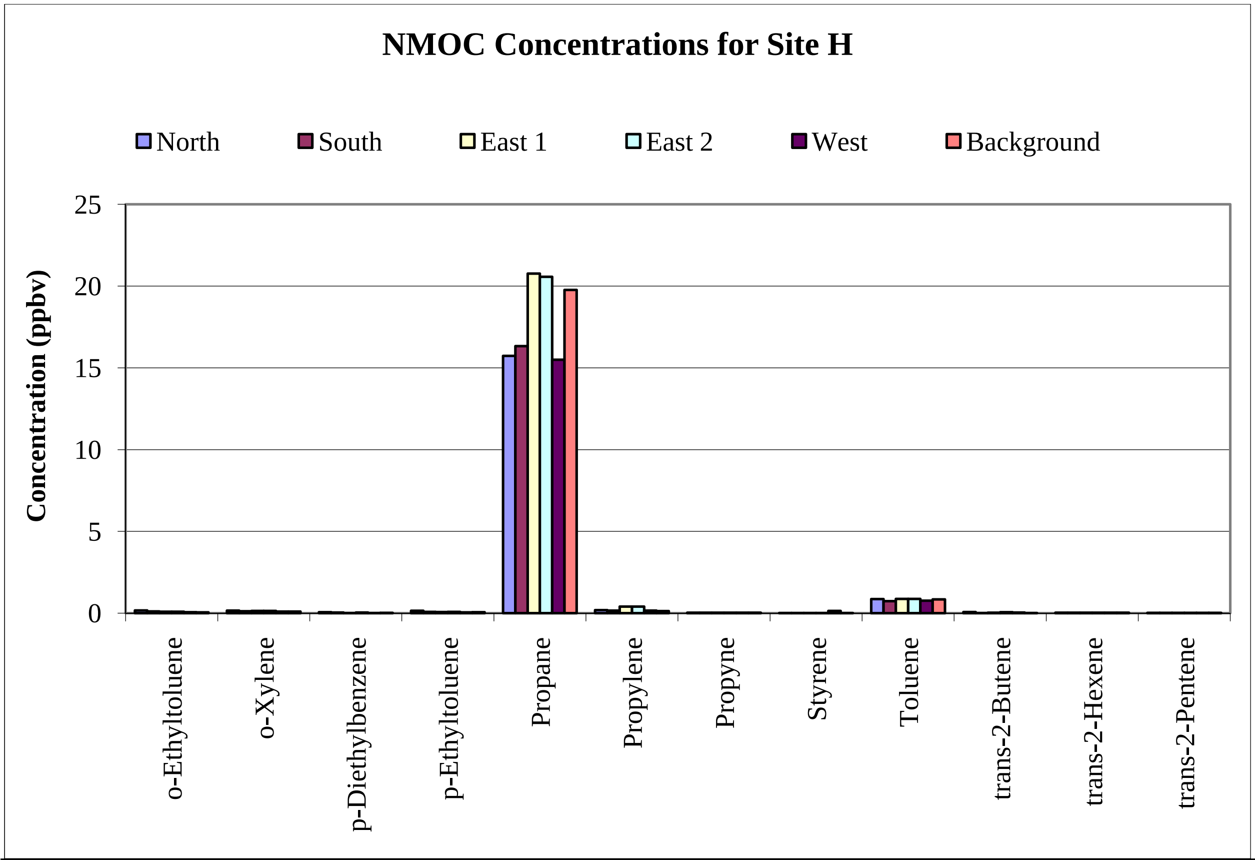

NMOC Concentrations for Site H
North
South
East 1
East 2
West
Background
Concentration (ppbv)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1-Tridecene
1-Undecene
2,2,3-Trimethylpentane
2,2,4-Trimethylpentane
2,2-Dimethylbutane
2,3,4-Trimethylpentane
2,3-Dimethylbutane
2,3-Dimethylpentane
2,4-Dimethylpentane
2-Ethyl-1-butene
2-Methyl-1-butene

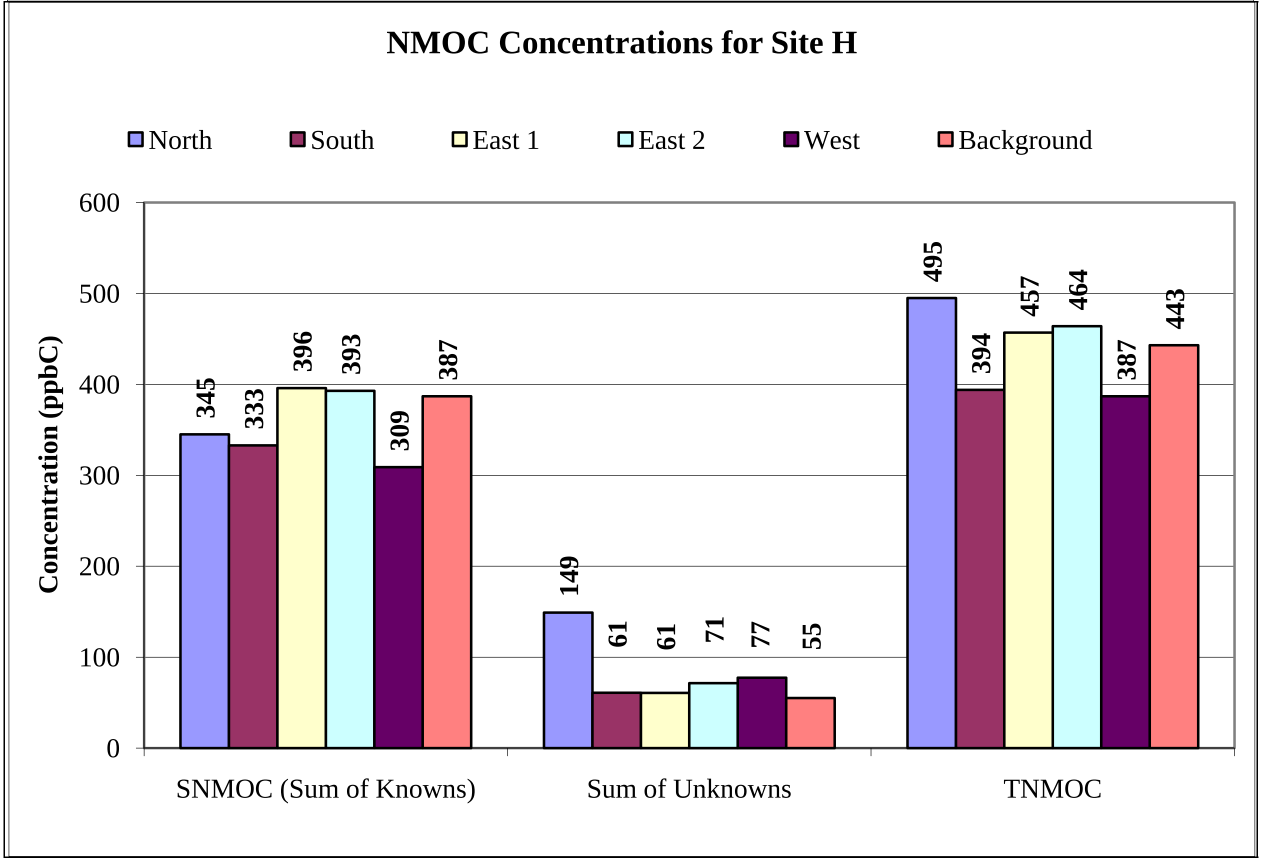

NMOC Concentrations for Site H
North
South
East 1
East 2
West
Background
Concentration (ppbv)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2-Methyl-1-pentene
2-Methyl-2-butene
2-Methylheptane
2-Methylhexane
2-Methylpentane
3-Methyl-1-butene
3-Methylheptane
3-Methylhexane
3-Methylpentane
4-Methyl-1-pentene
Acetylene


NMOC Concentrations for Site H
North
South
East 1
East 2
West
Background
Concentration (ppbv)
80
70
60
50
40
30
20
10
0
a-Pinene
Benzene
b-Pinene
cis-2-Butene
cis-2-Hexene
cis-2-Pentene
Cyclohexane
Cyclopentane
Cyclopentene
Ethane
Ethylbenzene


NMOC Concentrations for Site H
North
South
East 1
East 2
West
Background
Concentration (ppbv)
6
5
4
3
2
1
0
Ethylene
Isobutane
Isobutene/1-Butene
Isopentane
Isoprene
Isopropylbenzene
m-Diethylbenzene
Methylcyclohexane
Methylcyclopentane
m-Ethyltoluene
m-Xylene/p-Xylene


NMOC Concentrations for Site H
North
South
East 1
East 2
West
Background
Concentration (ppbv)
6
5
4
3
2
1
0
n-Butane
n-Decane
n-Dodecane
n-Heptane
n-Hexane
n-Nonane
n-Octane
n-Pentane
n-Propylbenzene
n-Tridecane
n-Undecane


NMOC Concentrations for Site H
North
South
East 1
East 2
West
Background
Concentration (ppbv)
25
20
15
10
5
0
o-Ethyltoluene
o-Xylene
p-Diethylbenzene
p-Ethyltoluene
Propane
Propylene
Propyne
Styrene
Toluene
trans-2-Butene
trans-2-Hexene
trans-2-Pentene


NMOC Concentrations for Site H
North
South
East 1
East 2
West
Background
Concentration (ppbC)
600
500
400
300
200
100
0
345
333
396
393
309
387
149
61
61
71
77
55
495
394
457
464
387
443
SNMOC (Sum of Knowns)
Sum of Unknowns
TNMOC